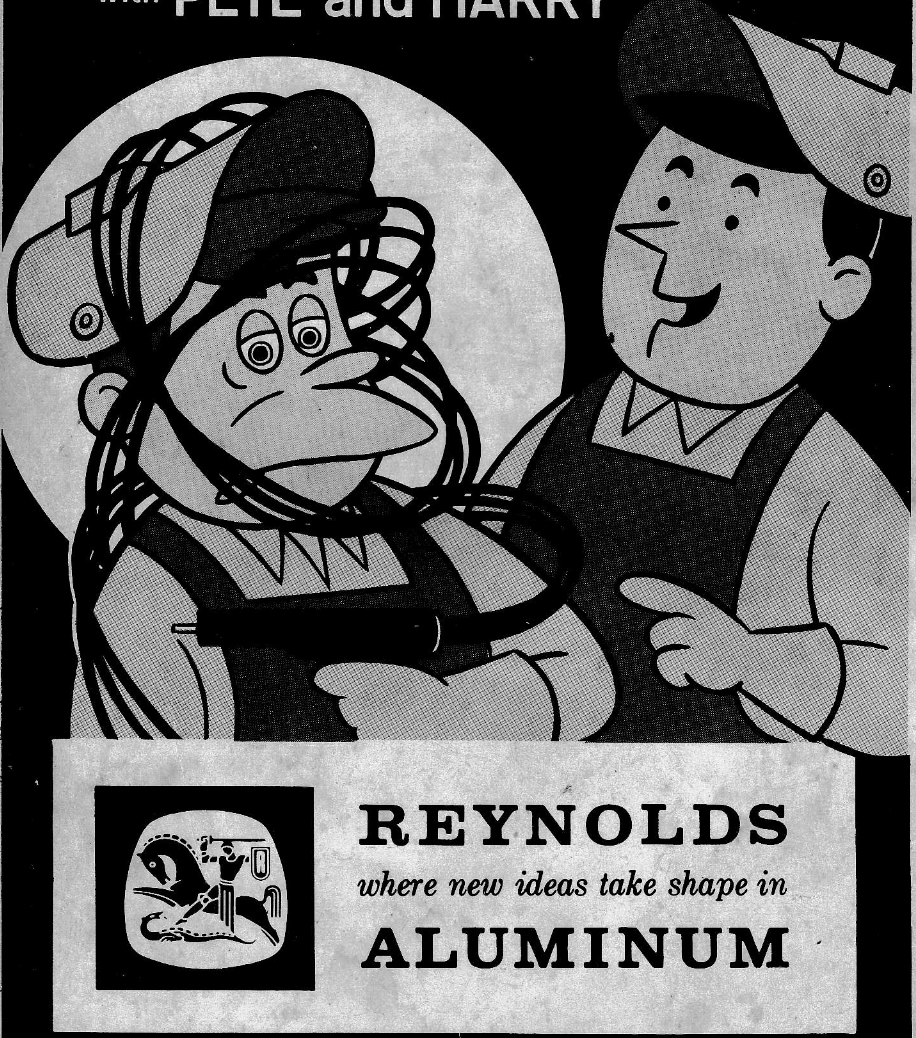
MIG WELDING ALUMINUM

with PETE and HARRY



REYNOLDS
where new ideas take shape in
ALUMINUM

CAST

INSTRUCTOR .... AL JONES
BOSS .... GEORGE DONAHUE
WELDOR .... PETE
WELDOR .... HARRY

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A Publication of . . .

REYNOLDS METALS COMPANY

P.O. Box 2346, Richmond, Virginia, U.S.A.

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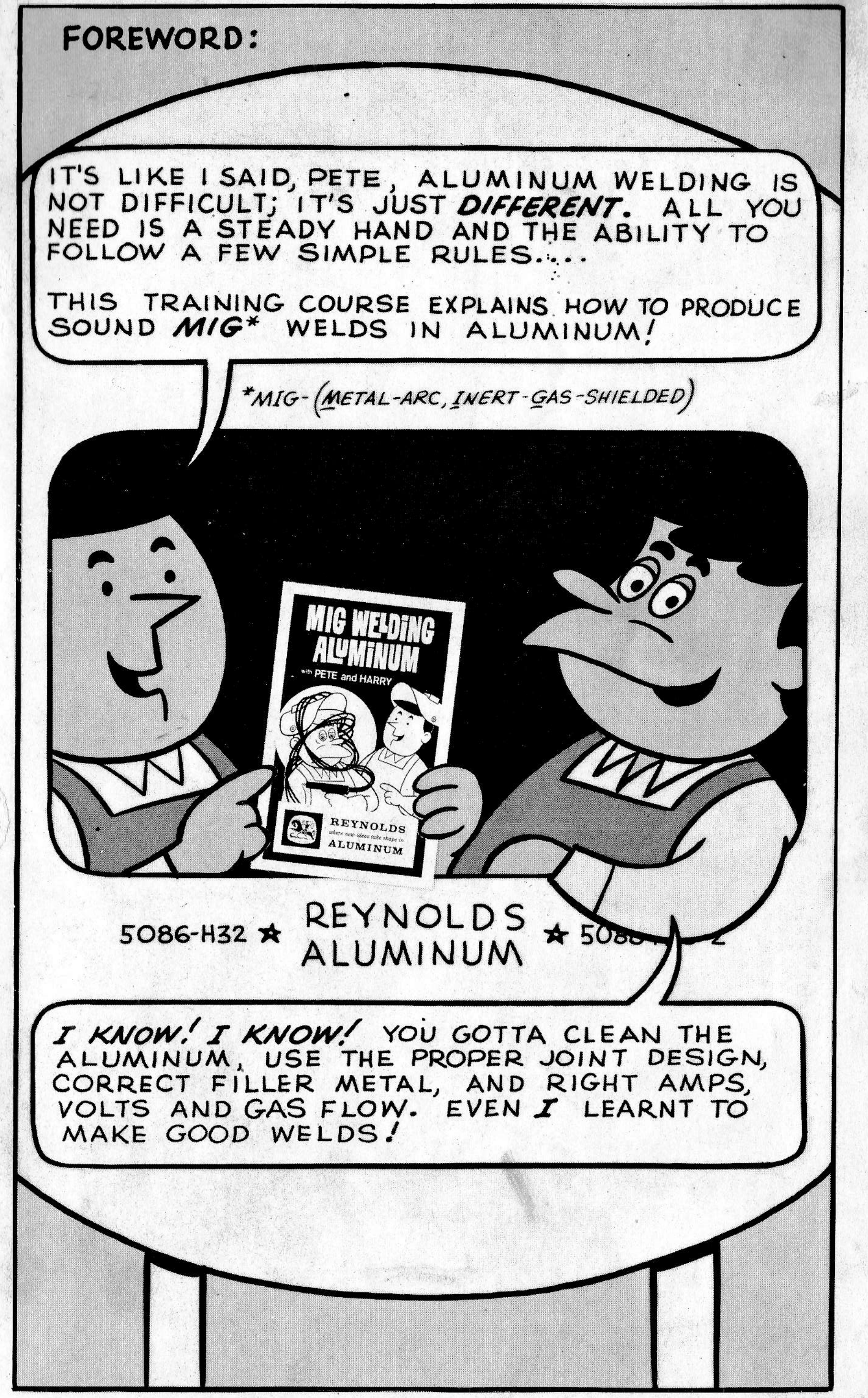
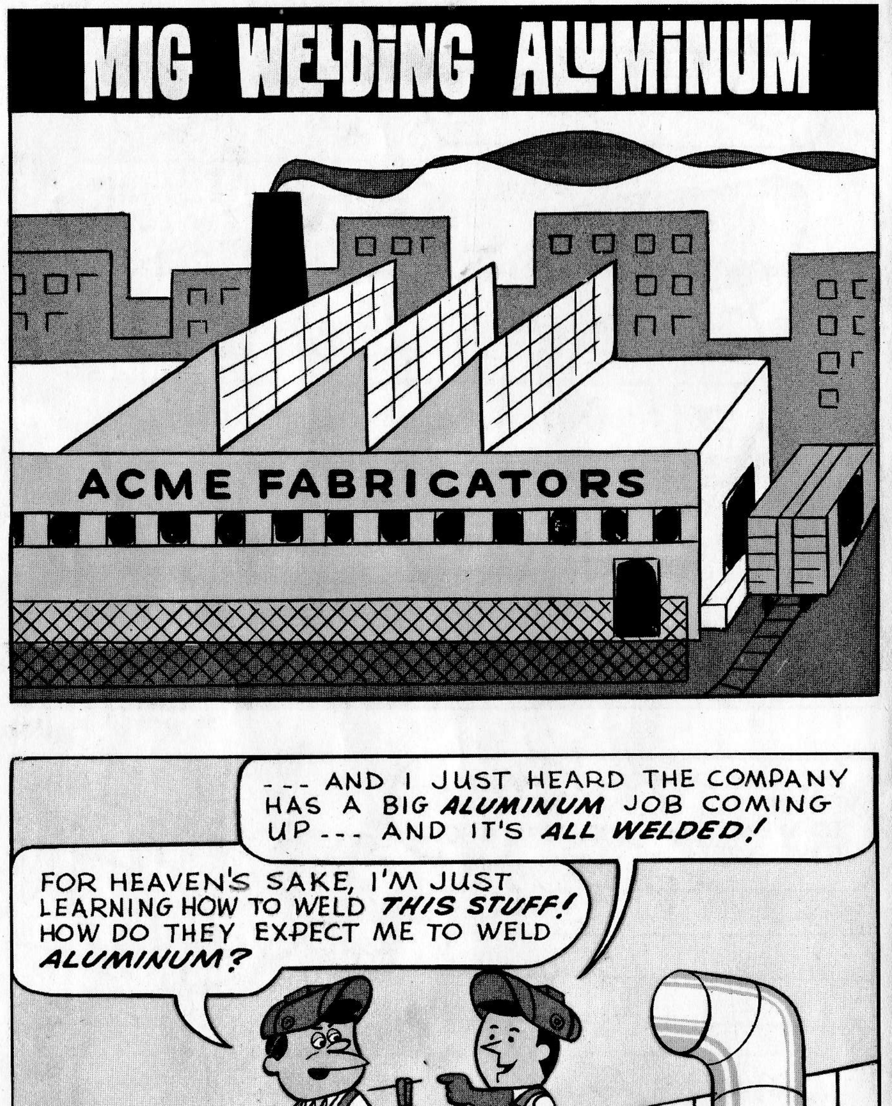
Litho in U.S.A. Script writer and technical consultant: R. A. Hay, Engineering Services Department. Editor and producer: G. W. Birdsall, Director, Editorial Services. Cartoons by W. S. Martin; Martin—Remick—Moore, Inc., Richmond, Va.



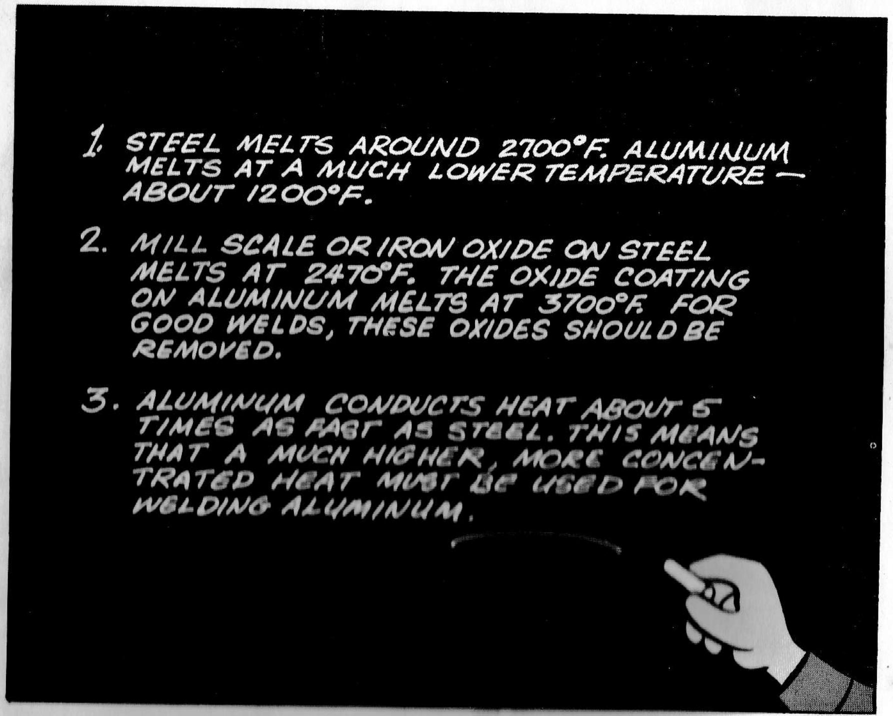

MIG WELDING ALUMINUM
ACME FABRICATORS
FOR HEAVEN'S SAKE, I'M JUST LEARNING HOW TO WELD *THIS STUFF!* HOW DO THEY EXPECT ME TO WELD *ALUMINUM?*
--- AND I JUST HEARD THE COMPANY HAS A BIG *ALUMINUM* JOB COMING UP --- AND IT'S *ALL WELDED!*

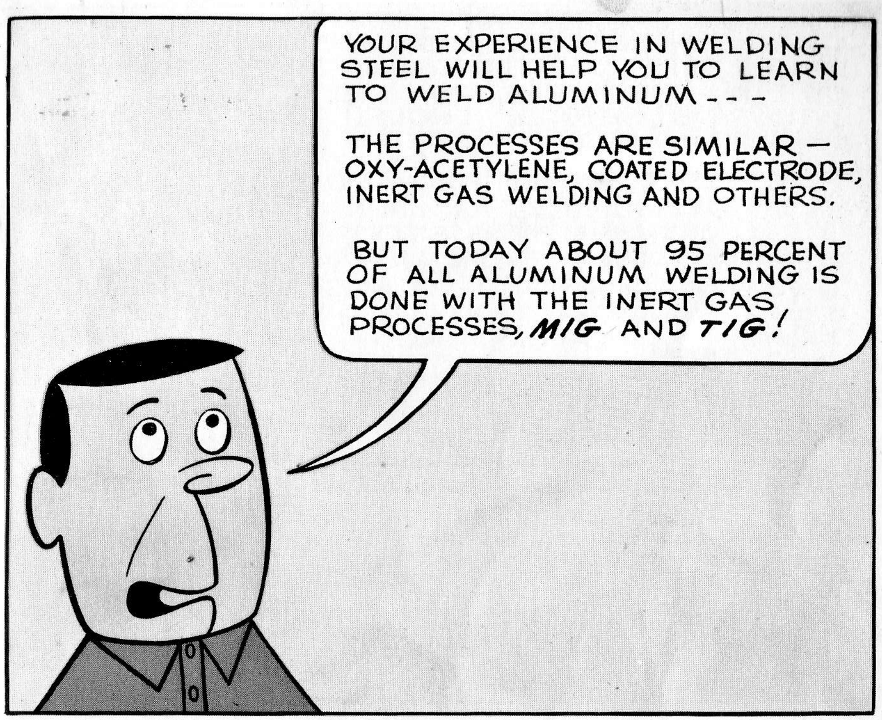
WELL, HERE COMES THE BOSS! ASK HIM!
HI, MR. DONAHUE, HARRY TELLS ME WE'RE GONNA HAVE TO WELD ALUMINUM IN ABOUT TWO WEEKS!

YEP! THAT'S RIGHT... AND YOU BOYS ARE GOING TO SCHOOL TO LEARN HOW TO DO IT!
WELDING SCHOOL
AL JONES - INSTRUCTOR

YES, WE HAVE A FINE ALUMINUM WELDING COURSE AND THE LATEST INERT GAS WELDING EQUIPMENT!
AL JONES, INSTRUCTOR
PSST, HARRY, WHAT'S INERT GAS?
SHH--BE QUIET. LET HIM TELL US!

GENTLEMEN, I KNOW MOST OF YOU ARE FAMILIAR WITH WELDING STEEL — HOWEVER, THERE ARE SEVERAL POINTS YOU MUST REMEMBER WHEN WELDING ALUMINUM.

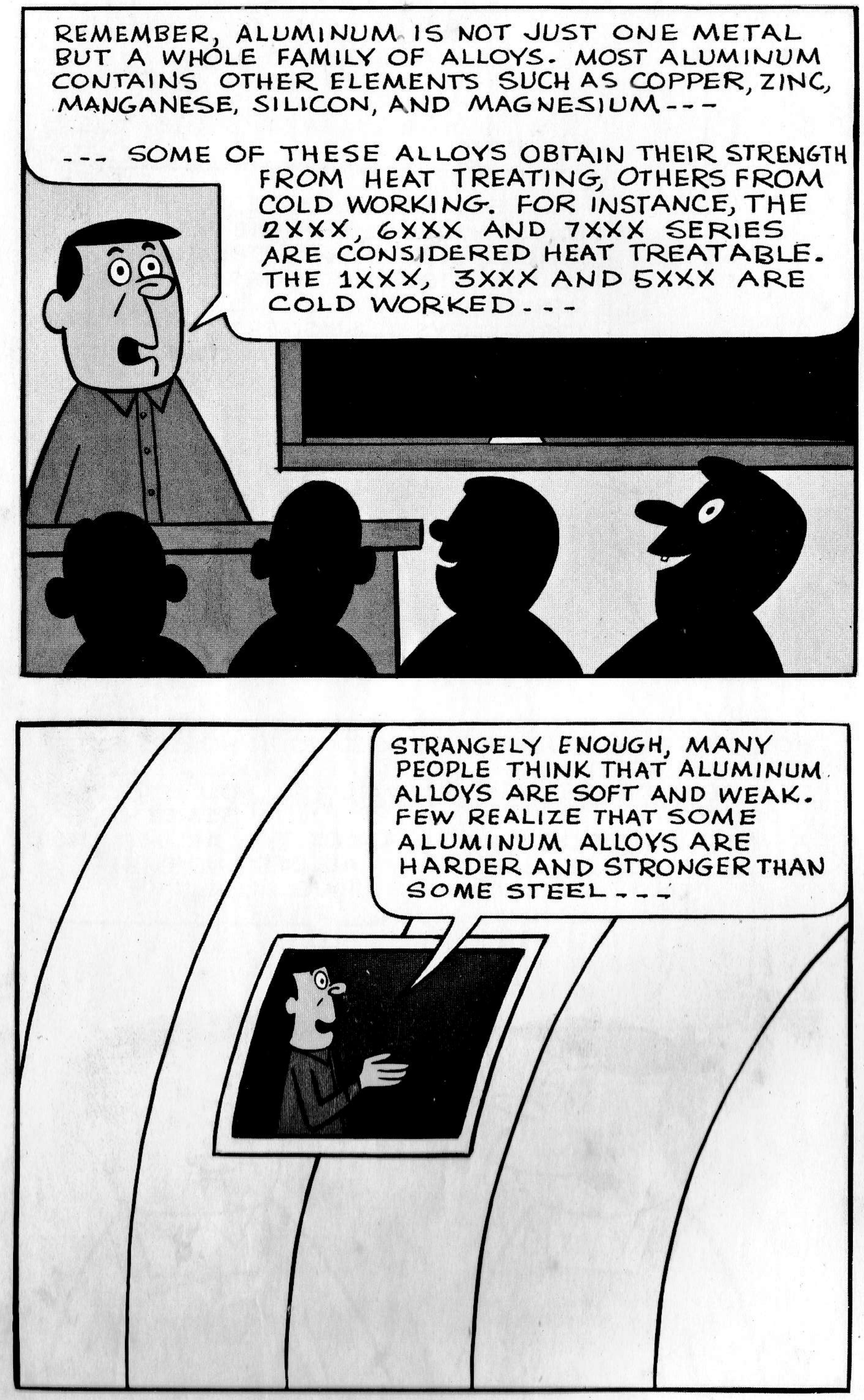

1. STEEL MELTS AROUND 2700°F. ALUMINUM MELTS AT A MUCH LOWER TEMPERATURE — ABOUT 1200°F.
2. MILL SCALE OR IRON OXIDE ON STEEL MELTS AT 2470°F. THE OXIDE COATING ON ALUMINUM MELTS AT 3700°F. FOR GOOD WELDS, THESE OXIDES SHOULD BE REMOVED.
3. ALUMINUM CONDUCTS HEAT ABOUT 5 TIMES AS FAST AS STEEL. THIS MEANS THAT A MUCH HIGHER, MORE CONCENTRATED HEAT MUST BE USED FOR WELDING ALUMINUM.

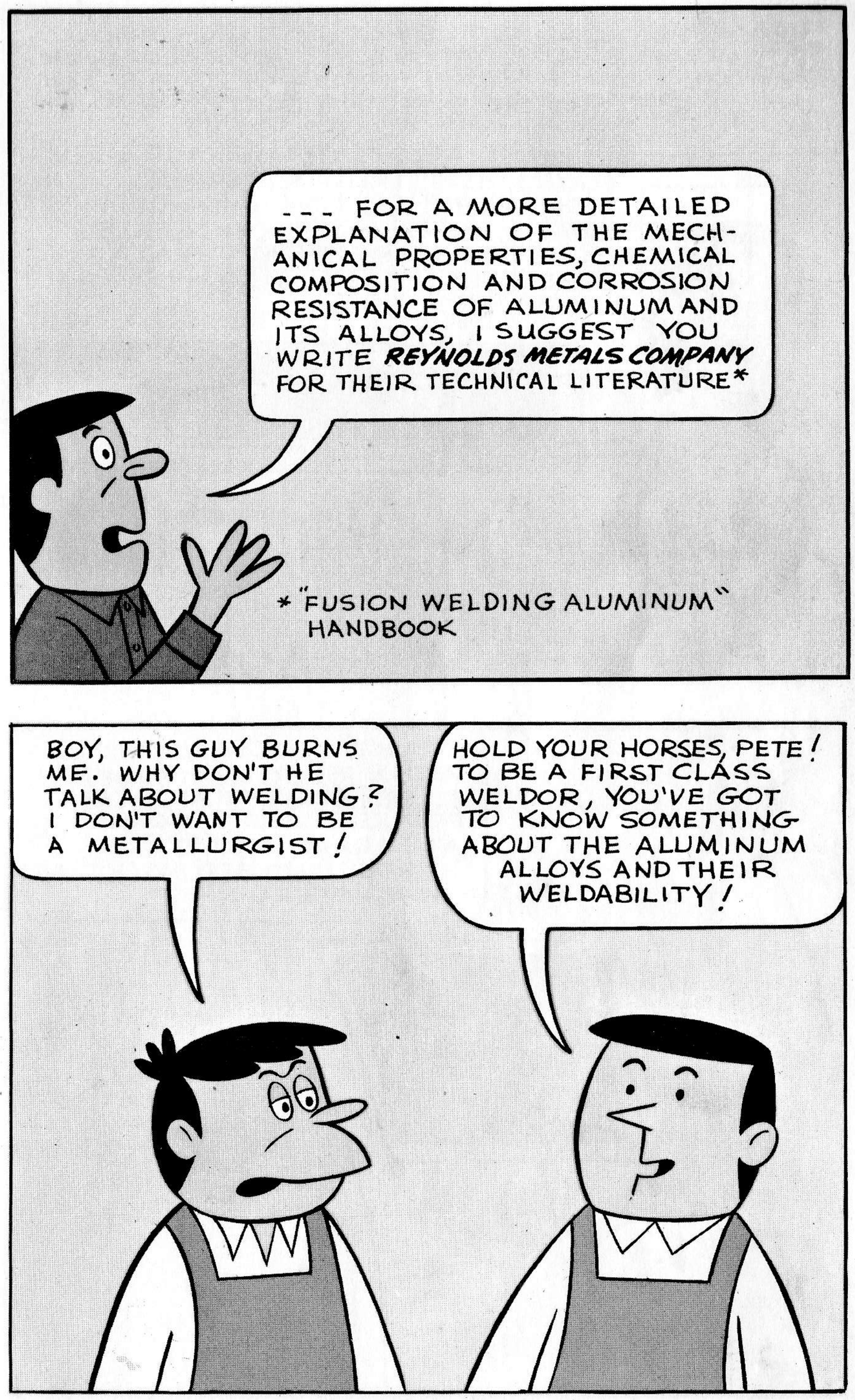

YOUR EXPERIENCE IN WELDING STEEL WILL HELP YOU TO LEARN TO WELD ALUMINUM - - -
THE PROCESSES ARE SIMILAR — OXY-ACETYLENE, COATED ELECTRODE, INERT GAS WELDING AND OTHERS.
BUT TODAY ABOUT 95 PERCENT OF ALL ALUMINUM WELDING IS DONE WITH THE INERT GAS PROCESSES, MIG AND TIG!

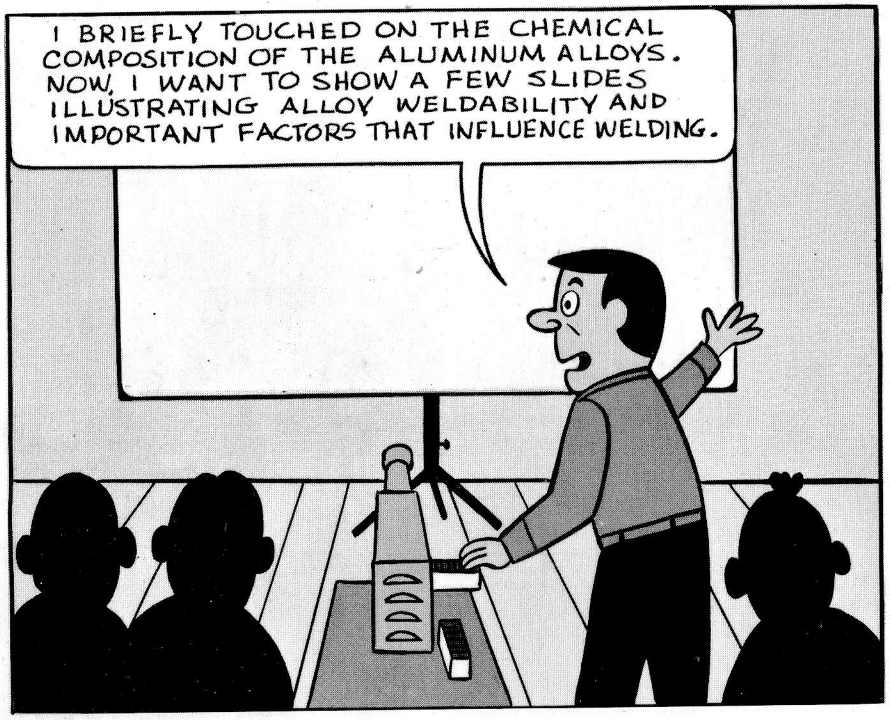
PSST- THERE HE GOES AGAIN WITH THAT FOREIGN TALK - INERT GAS, MIG AND TIG. BOY! I'M CONFUSED BEFORE WE START!
WELL, FOR PETE'S SAKE, WHY DON'T YOU ASK HIM INSTEAD OF MUMBLING TO ME?

OKAY, I WILL--- MR. JONES, MR. JONES, HARRY HERE, JUST DON'T GET THE POINT ON THIS INERT, MIG, TIG BUSINESS-- WILL YOU BE GOOD ENOUGH TO EXPLAIN IT ?
OH, I WAS JUST GOING TO DO THAT. BY INERT GAS, I MEAN THE ARGON OR HELIUM USED FOR SHIELD-ING THE ELECTRODE AND WELD PUDDLE. ACCORDING TO WEBSTER, INERT MEANS INACTIVE OR SLUGGISH!

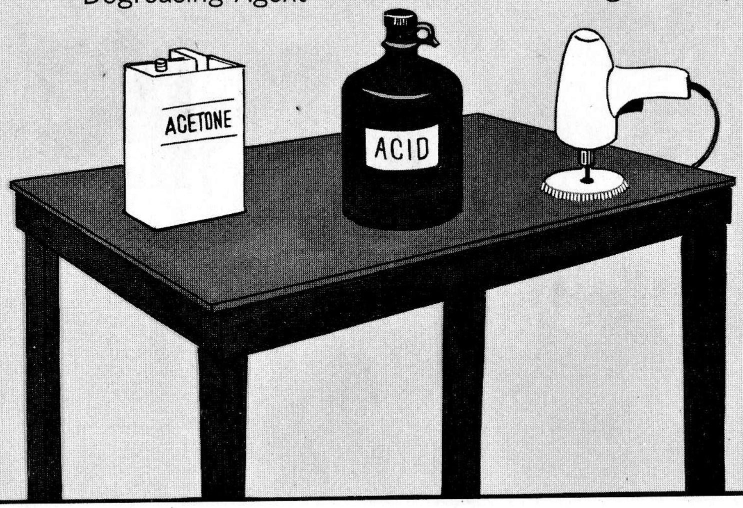
THERE YOU ARE, PETE! WHEN YOU THINK OF INERT, THINK OF YOURSELF; YOU'RE SLUGGISH AND INACTIVE MOST OF THE TIME!
--- AS FOR MIG THAT MEANS METAL-ARC, INERT-GAS SHIELDED WELDING. YOU CAN SEE THAT WAS TOO LONG, SO WE SHORTEN-ED IT TO MIG. THIS WELDING COURSE WILL BE ON MIG WELDING!


REMEMBER, ALUMINUM IS NOT JUST ONE METAL BUT A WHOLE FAMILY OF ALLOYS. MOST ALUMINUM CONTAINS OTHER ELEMENTS SUCH AS COPPER, ZINC, MANGANESE, SILICON, AND MAGNESIUM---
--- SOME OF THESE ALLOYS OBTAIN THEIR STRENGTH FROM HEAT TREATING, OTHERS FROM COLD WORKING. FOR INSTANCE, THE 2XXX, 6XXX AND 7XXX SERIES ARE CONSIDERED HEAT TREATABLE. THE 1XXX, 3XXX AND 5XXX ARE COLD WORKED---
STRANGELY ENOUGH, MANY PEOPLE THINK THAT ALUMINUM ALLOYS ARE SOFT AND WEAK. FEW REALIZE THAT SOME ALUMINUM ALLOYS ARE HARDER AND STRONGER THAN SOME STEEL---


--- FOR A MORE DETAILED EXPLANATION OF THE MECHANICAL PROPERTIES, CHEMICAL COMPOSITION AND CORROSION RESISTANCE OF ALUMINUM AND ITS ALLOYS, I SUGGEST YOU WRITE **REYNOLDS METALS COMPANY** FOR THEIR TECHNICAL LITERATURE*
* "FUSION WELDING ALUMINUM" HANDBOOK
BOY, THIS GUY BURNS ME. WHY DON'T HE TALK ABOUT WELDING? I DON'T WANT TO BE A METALLURGIST!
HOLD YOUR HORSES, PETE! TO BE A FIRST CLASS WELDOR, YOU'VE GOT TO KNOW SOMETHING ABOUT THE ALUMINUM ALLOYS AND THEIR WELDABILITY!



PROPER CLEANING OF BASE MATERIAL

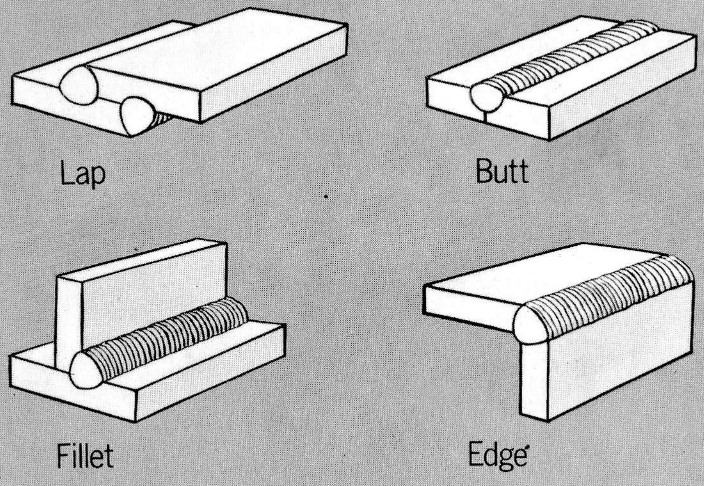


CORRECT FILLER MATERIAL FOR MIG WELDING

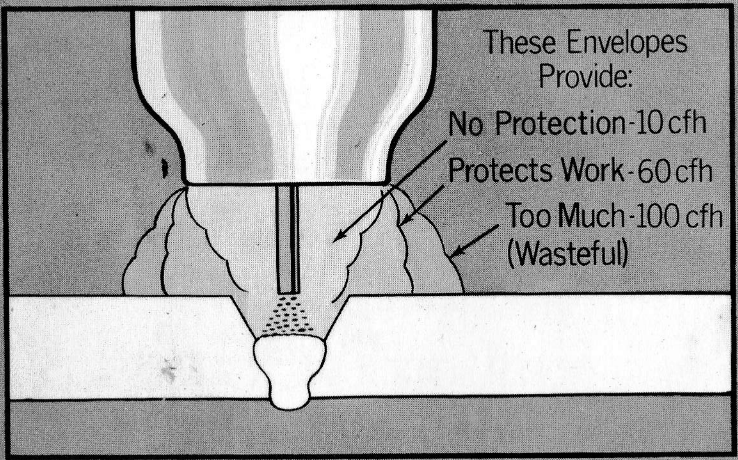
Alloy Combinations (2nd part \ 1st part)	6061 6063 6101 6151	5083 5456	5454	5086 5154	5052
5052	4043 5154	5356	5356 5554	5356 5154	5154 4043
5086 5154	5356 5154	5356	5356 5554	5356 5154	
5454	5356 5554	5356 5554	5554 5356		
5083 5456	5356	5356			
6061 6063 6101 6151	5154 4043				

Note: 1. 5183 or 5556 may be used in place of 5356.
2. 5254 may be used in place of 5154.

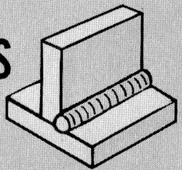
TYPICAL WELDED JOINTS



CORRECT SHIELDING GAS



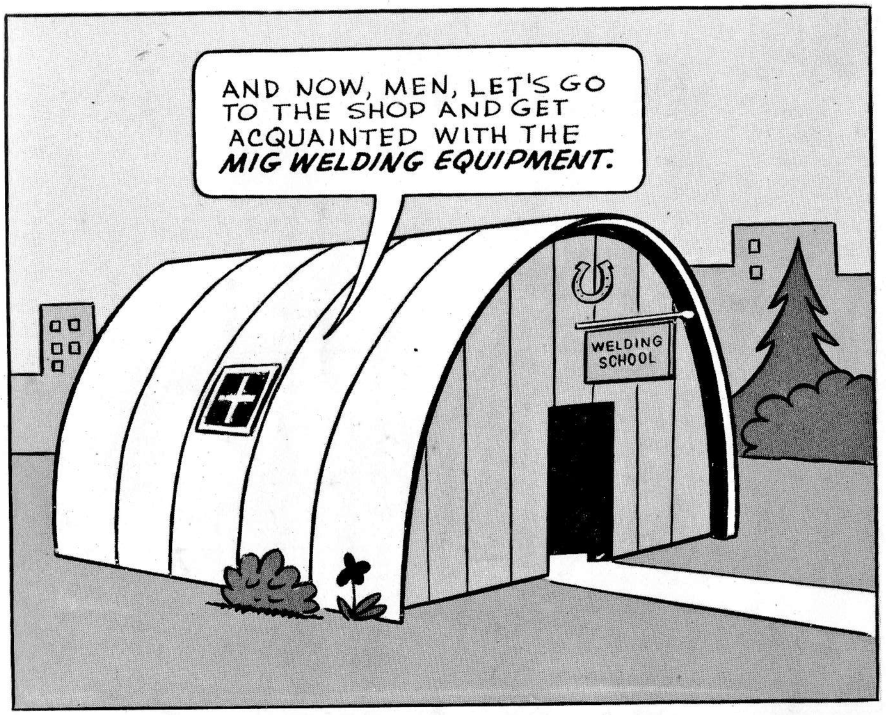
CORRECT WELD CONDITIONS FOR FILLET WELDS

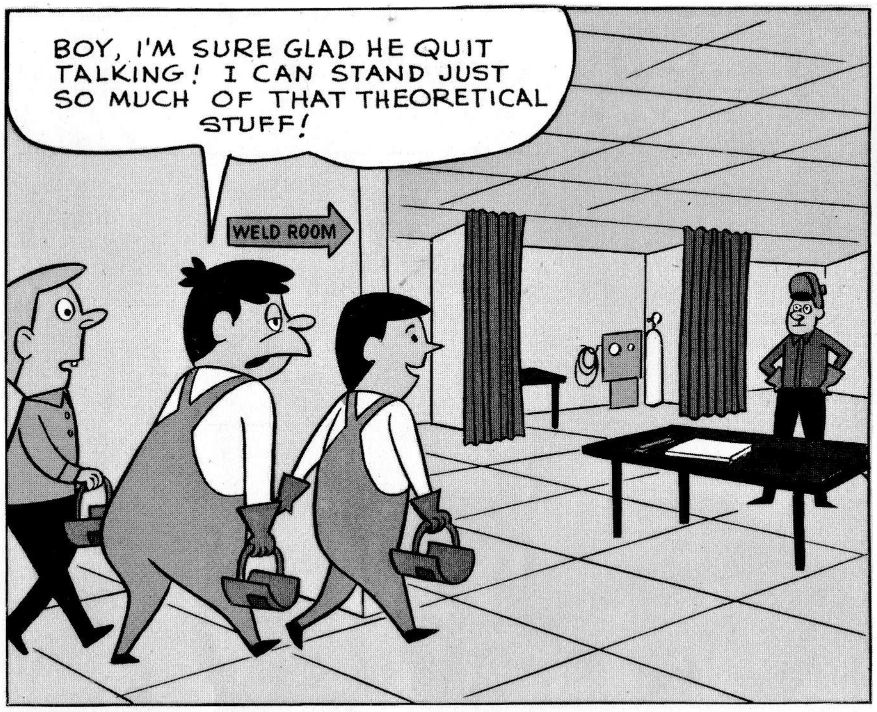


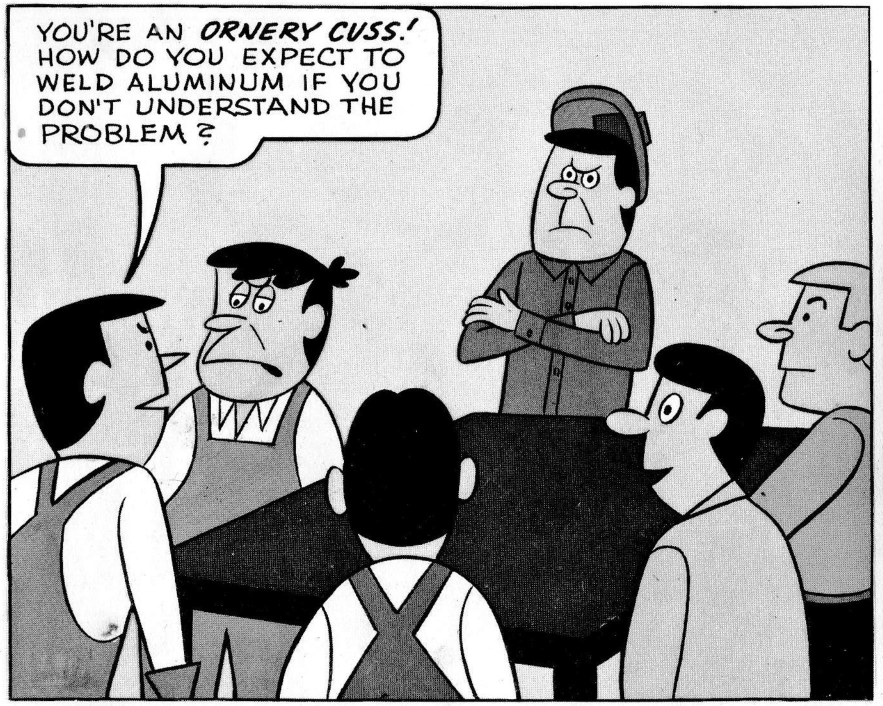
Stock Thickness inch	Position	Welding: Passes Per Joint	Welding: Speed inch/min/Pass	Arc: amps dc	Arc: volts	Argon: Flow Rate cf/hr	Electrode: Diameter inch	Electrode: Used per 100 ft lb
1/4	Flat	1	24	225	25-29	40	1/16	7
	H & V	1	20	200	25-29	45	1/16	7
	Ovhd	1	20	200	25-29	50	1/16	7
3/8	Flat	3	30	300	25-29	50	1/16	17
	H & V	3	24	200	25-29	50	1/16	17
	Ovhd	3	24	220	25-29	60	1/16	17
1/2	Flat	3	16	340	25-31	60	3/32	30
	H & V	3	12	225	25-29	60	1/16	30
	Ovhd	5	18	230	25-29	60	1/16	30
3/4	Flat	4	16	375	25-31	60	3/32	66
	H & V	4	8	260	25-29	60	1/16	66
	Ovhd	10	18	275	25-29	80	1/16	66
1	Flat	4	8	425	25-31	60	3/32	120
	H & V	6	6	260	25-29	80	1/16	120
	Ovhd	14	18	290	25-29	80	1/16	120

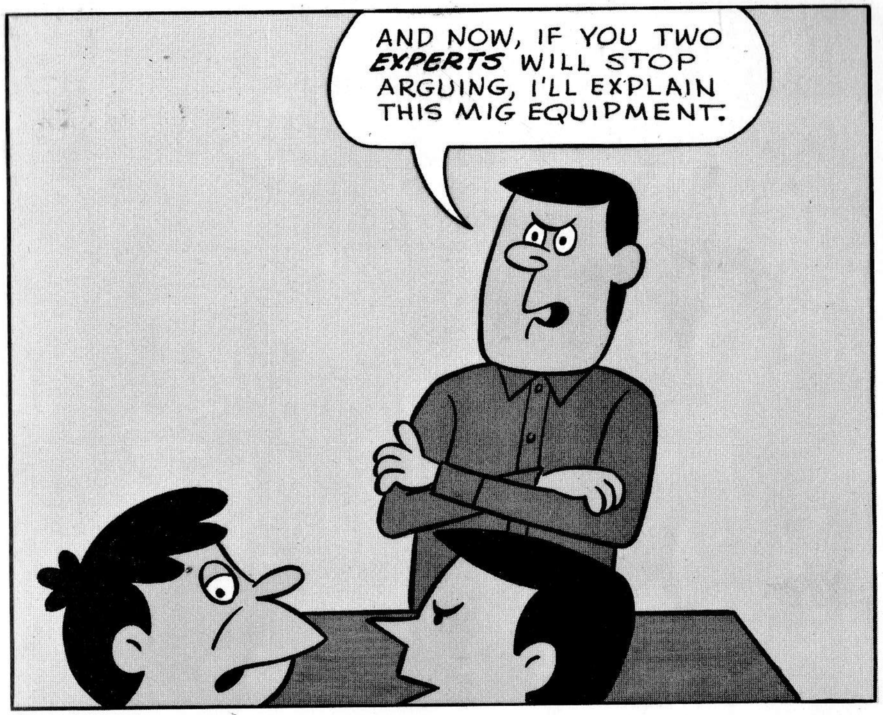
SUMMARY

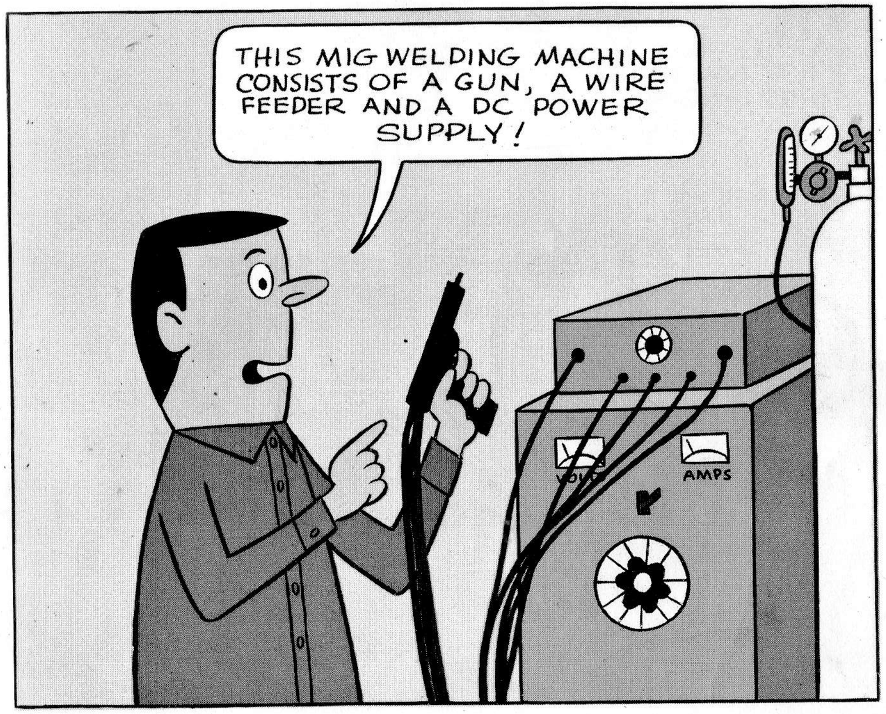
- ✓ REMOVE OIL, GREASE & OXIDE FROM SURFACE OF JOINT BEFORE WELDING
- ✓ USE FILLER METAL RECOMMENDED FOR A SPECIFIC ALLOY
- ✓ USE PROPER JOINT DESIGN AND CORRECT WELD CONDITIONS

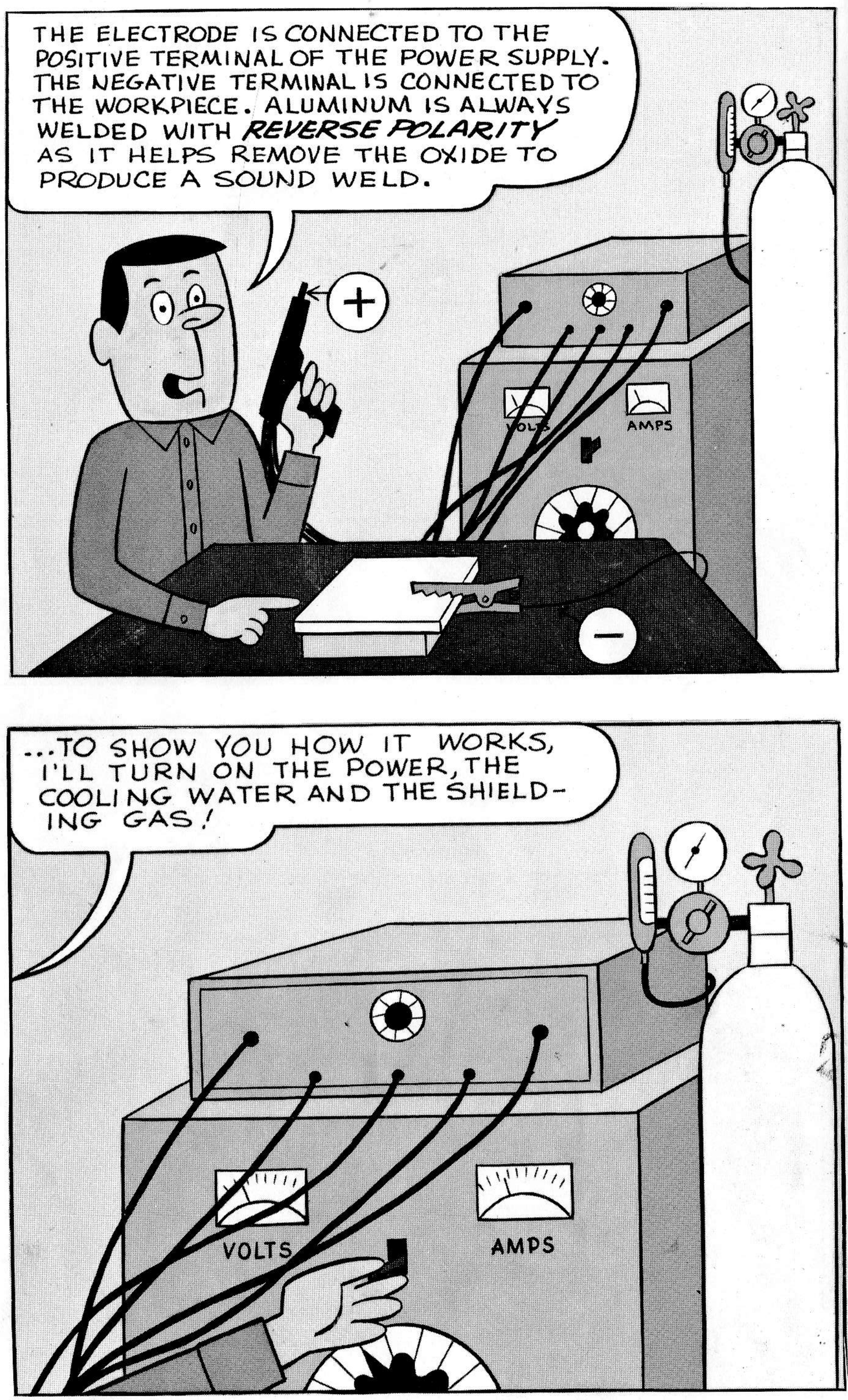



BOY, I'M SURE GLAD HE QUIT TALKING! I CAN STAND JUST SO MUCH OF THAT THEORETICAL STUFF!
WELD ROOM


YOU'RE AN ***ORNERY CUSS!*** HOW DO YOU EXPECT TO WELD ALUMINUM IF YOU DON'T UNDERSTAND THE PROBLEM?

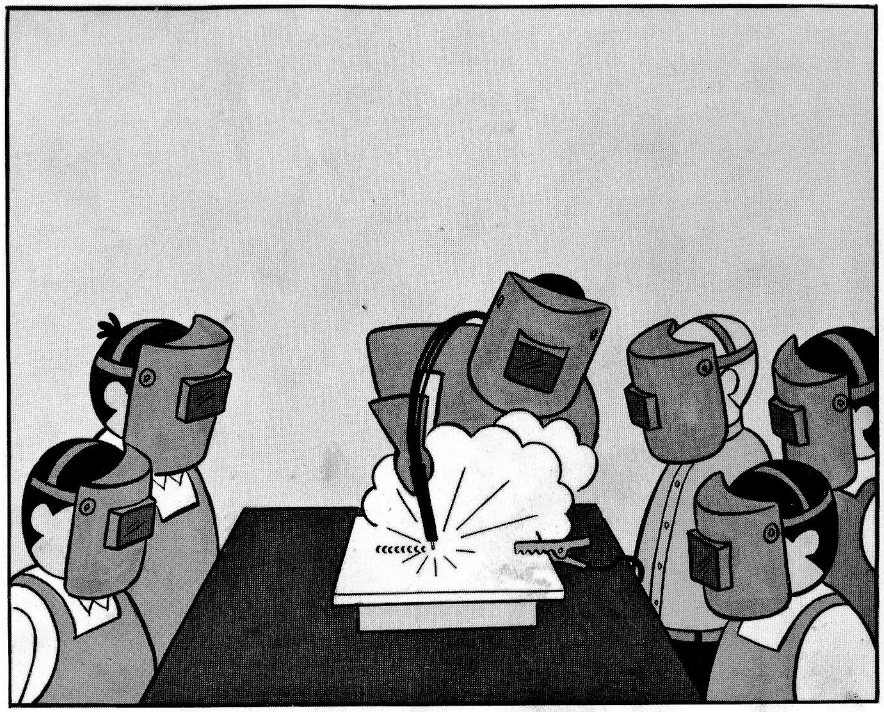

AND NOW, IF YOU TWO ***EXPERTS*** WILL STOP ARGUING, I'LL EXPLAIN THIS MIG EQUIPMENT.

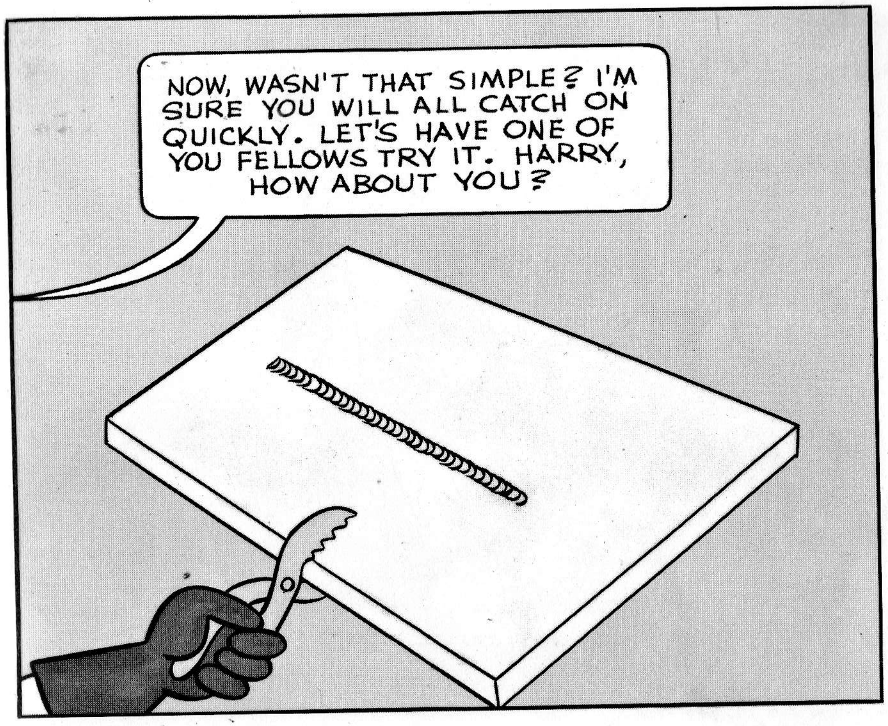

THIS MIG WELDING MACHINE CONSISTS OF A GUN, A WIRE FEEDER AND A DC POWER SUPPLY!
AMPS


THE ELECTRODE IS CONNECTED TO THE POSITIVE TERMINAL OF THE POWER SUPPLY. THE NEGATIVE TERMINAL IS CONNECTED TO THE WORKPIECE. ALUMINUM IS ALWAYS WELDED WITH REVERSE POLARITY AS IT HELPS REMOVE THE OXIDE TO PRODUCE A SOUND WELD.
+
−
VOLTS
AMPS
...TO SHOW YOU HOW IT WORKS, I'LL TURN ON THE POWER, THE COOLING WATER AND THE SHIELD-ING GAS!
VOLTS
AMPS

NOTICE WHEN I PULL THE TRIGGER OF THIS GUN, THE CONTROLS WILL AUTOMATICALLY OPEN SOLENOID VALVES CONTROLLING THE FLOW OF GAS AND WATER AND WILL TURN ON THE POWER. NOW THE ELECTRODE IS "HOT" AND WE ARE READY TO WELD.
GAS
WATER
POWER
ELECTRODE
GAS
GADS! THAT GUY SURE CAN YAK. HE'S PROBABLY A LOUSY WELDOR.

AND NOW MEN, OUR FIRST LESSON WILL CONSIST OF LEARNING HOW TO ESTABLISH AN ARC WITHOUT STICKING TO THE WORK. REMEMBER, ALWAYS ***PROTECT YOUR EYES,*** AS THIS IS A VERY BRIGHT ARC.
---SHIELDS DOWN WHILE I LAY A WELD BEAD ON THIS PLATE. NOTICE THE NOZZLE OF THE GUN IS POINTED IN THE DIRECTION OF TRAVEL.



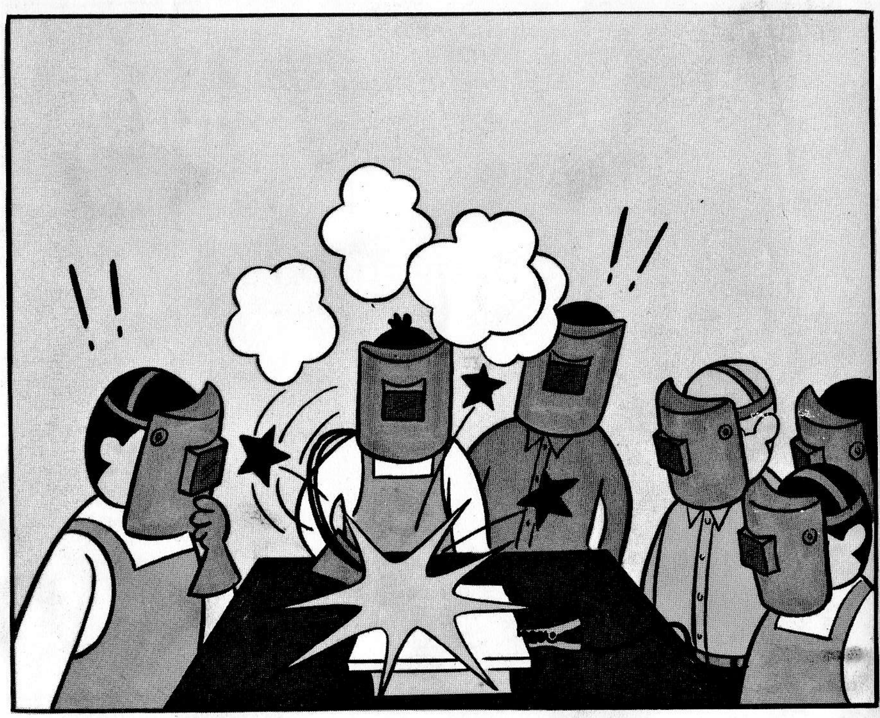

NOW, WASN'T THAT SIMPLE? I'M SURE YOU WILL ALL CATCH ON QUICKLY. LET'S HAVE ONE OF YOU FELLOWS TRY IT. HARRY, HOW ABOUT YOU?

OKAY, MR. JONES, I'LL GIVE IT A TRY. LOOKS SIMPLE TO ME.
REMEMBER, HARRY, ANGLE THE GUN AND USE A LIGHT SCRATCHING MOTION TO ESTABLISH THE ARC.

EXCELLENT, HARRY, YOU HAD NO PROBLEM AT ALL. SHOW THE BOYS YOUR WELD!

AND NOW, LET'S HAVE ANOTHER VOLUNTEER. HOW ABOUT YOU, PETE?

IF HARRY CAN DO IT, SO CAN I!
DON'T BURN YOURSELF PETE! THIS SURE IS A HOT ARC!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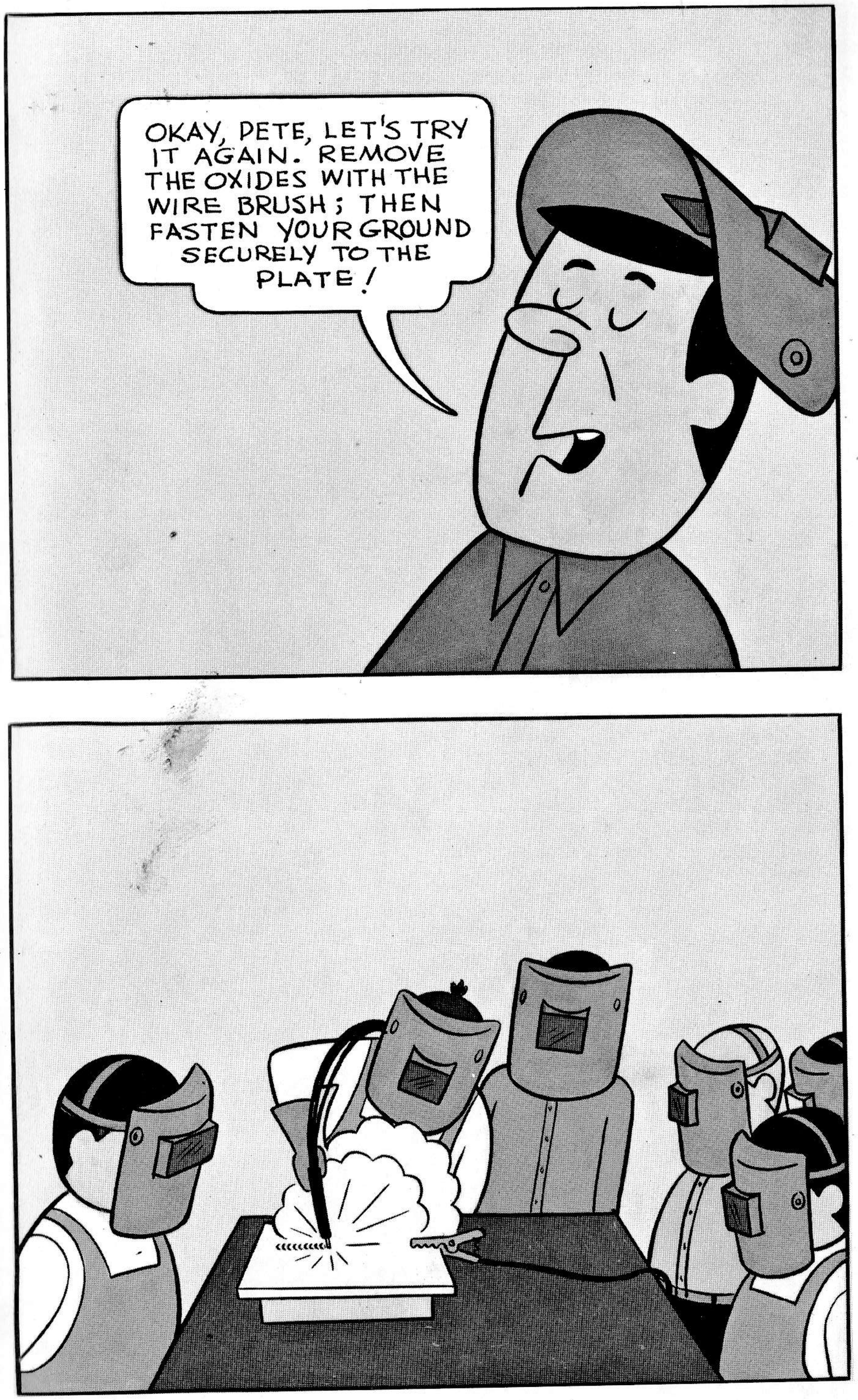
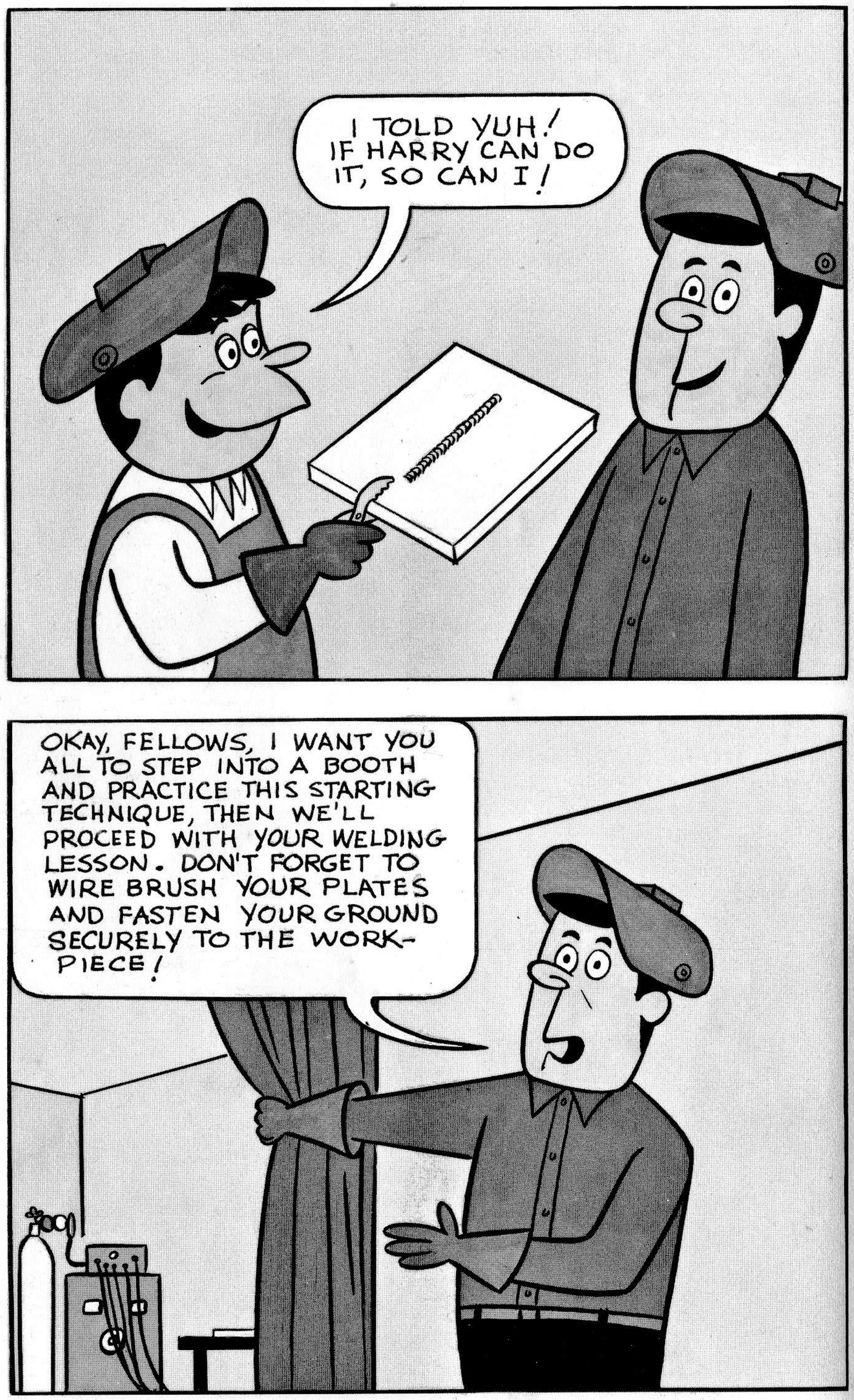
!!

LOOKS LIKE THE FOURTH OF JULY, PETE!
WANT A MATCH, PETE?
HOW ABOUT A LIGHT, PETE?

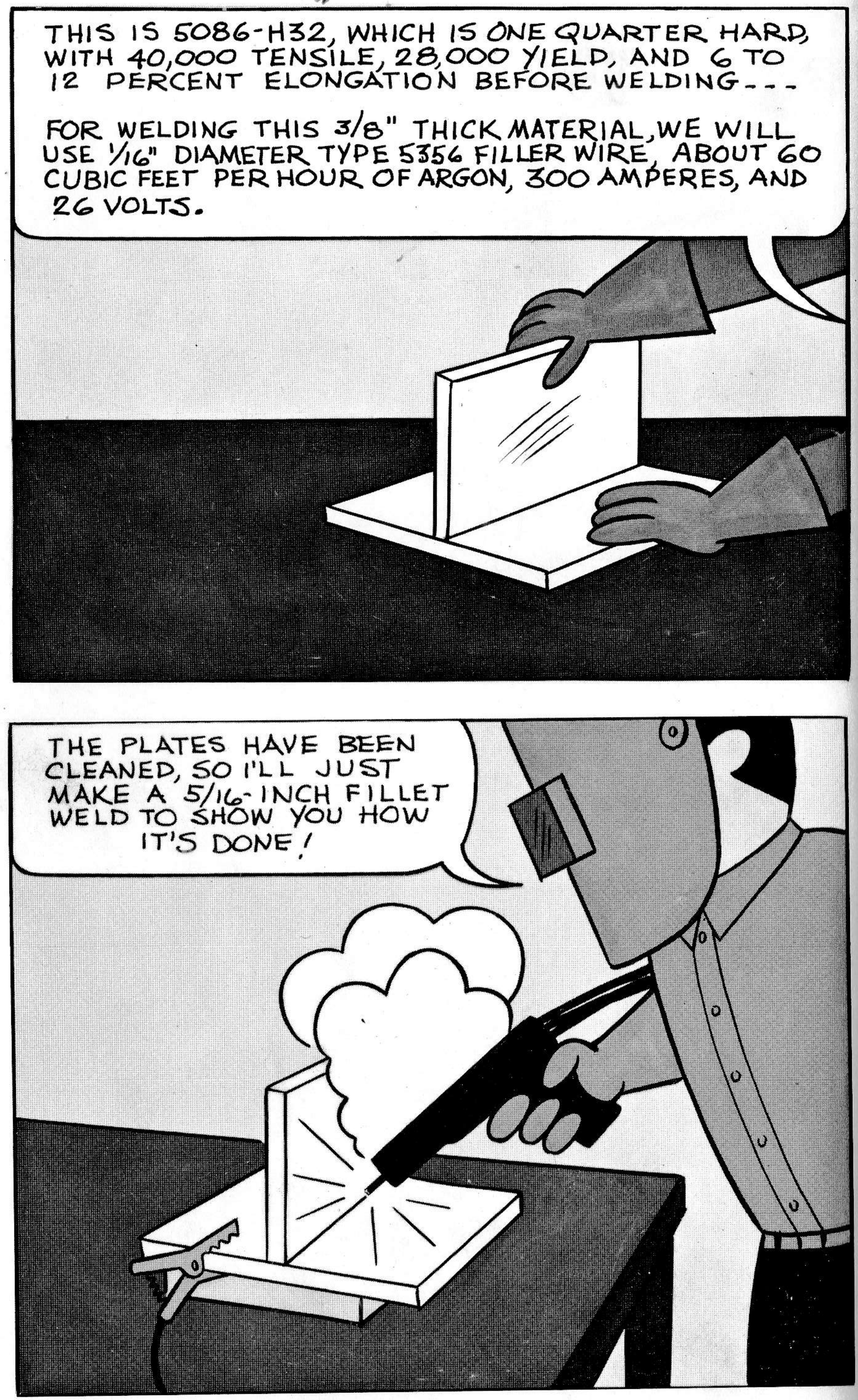
YOU'LL HAVE TO LEARN HOW TO SCRATCH BETTER THAN THAT, PETE. BESIDES, YOUR GROUND WAS NOT SECURELY FASTENED TO THE WORKPIECE. THAT ALWAYS CREATES ARCING.
YOU'RE WRONG, MR. JONES, PETE KNOWS HOW TO SCRATCH ALL RIGHT. HE'S ALWAYS SCRATCHING!

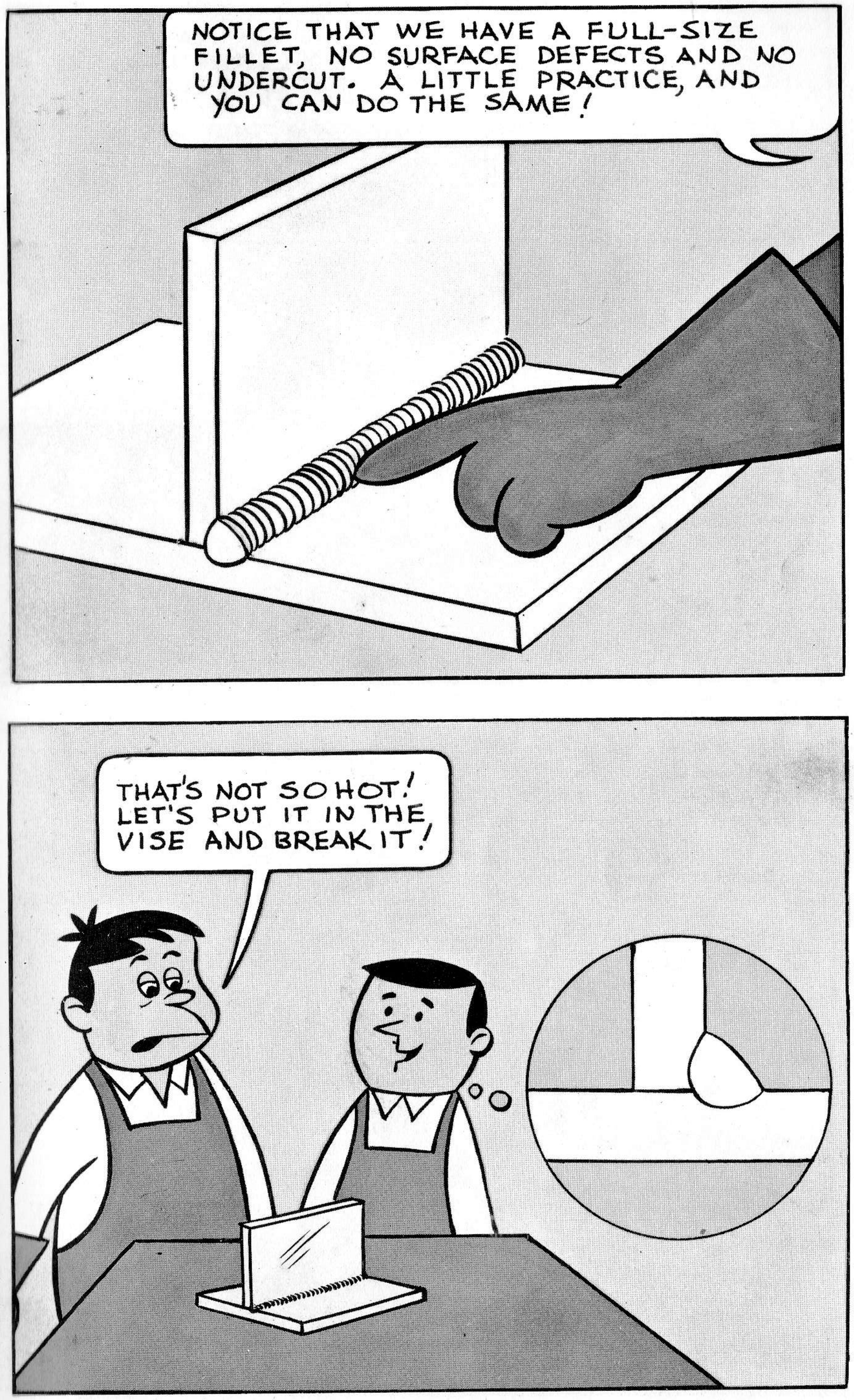

OKAY, PETE, LET'S TRY IT AGAIN. REMOVE THE OXIDES WITH THE WIRE BRUSH; THEN FASTEN YOUR GROUND SECURELY TO THE PLATE!


I TOLD YUH! IF HARRY CAN DO IT, SO CAN I!
OKAY, FELLOWS, I WANT YOU ALL TO STEP INTO A BOOTH AND PRACTICE THIS STARTING TECHNIQUE, THEN WE'LL PROCEED WITH YOUR WELDING LESSON. DON'T FORGET TO WIRE BRUSH YOUR PLATES AND FASTEN YOUR GROUND SECURELY TO THE WORK-PIECE!

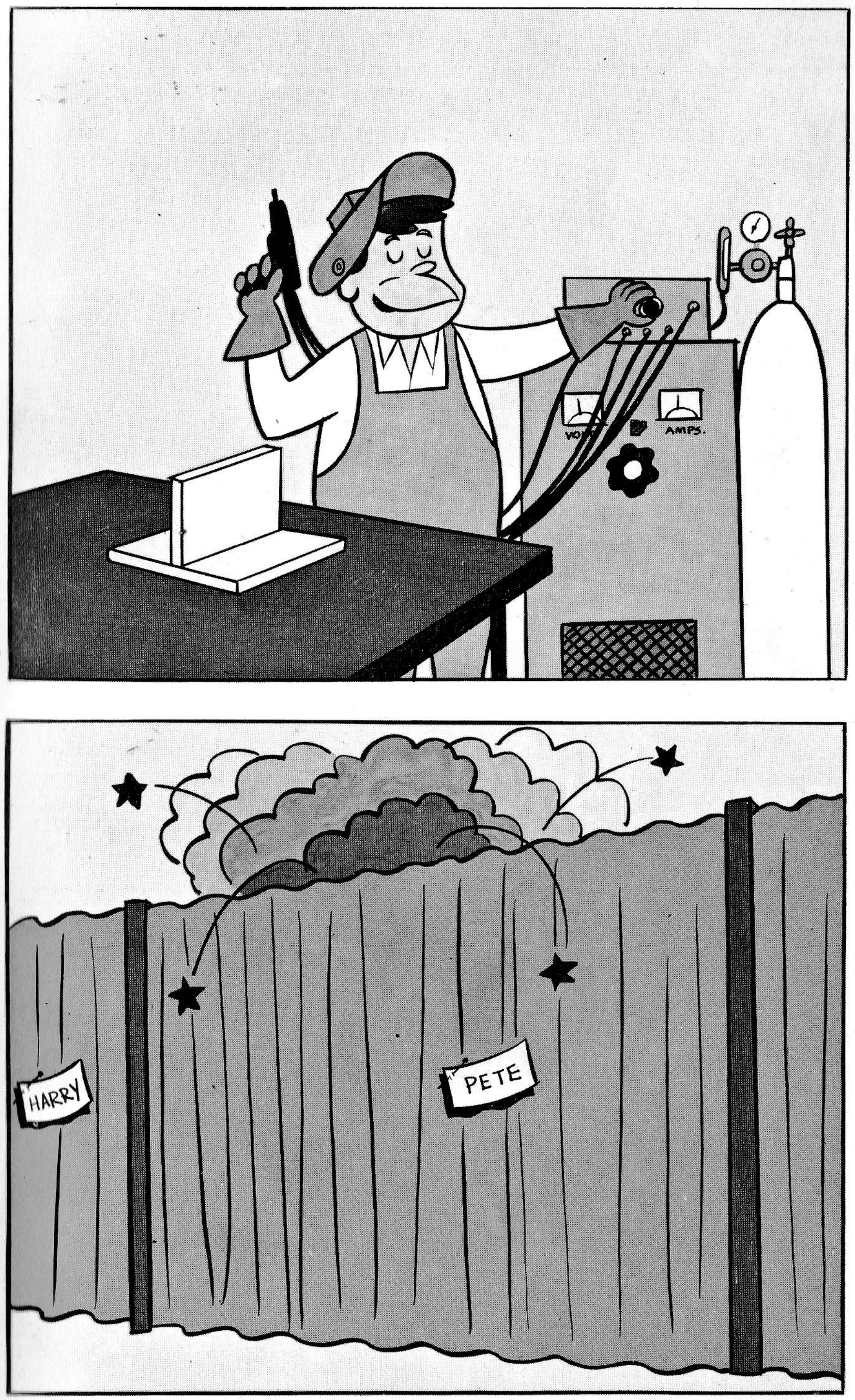
YOU FELLOWS ARE GOING TO BE WORKING ON AN IMPORTANT GOVERNMENT CONTRACT, SO I'LL SPEND AS MUCH TIME WITH YOU AS POSSIBLE 'TIL YOU QUALIFY!
I WANT YOU TO BECOME FAMILIAR WITH WELDING IN THE FLAT OR DOWNHAND POSITION. WE'LL TRY SOME FILLET WELDS FIRST.

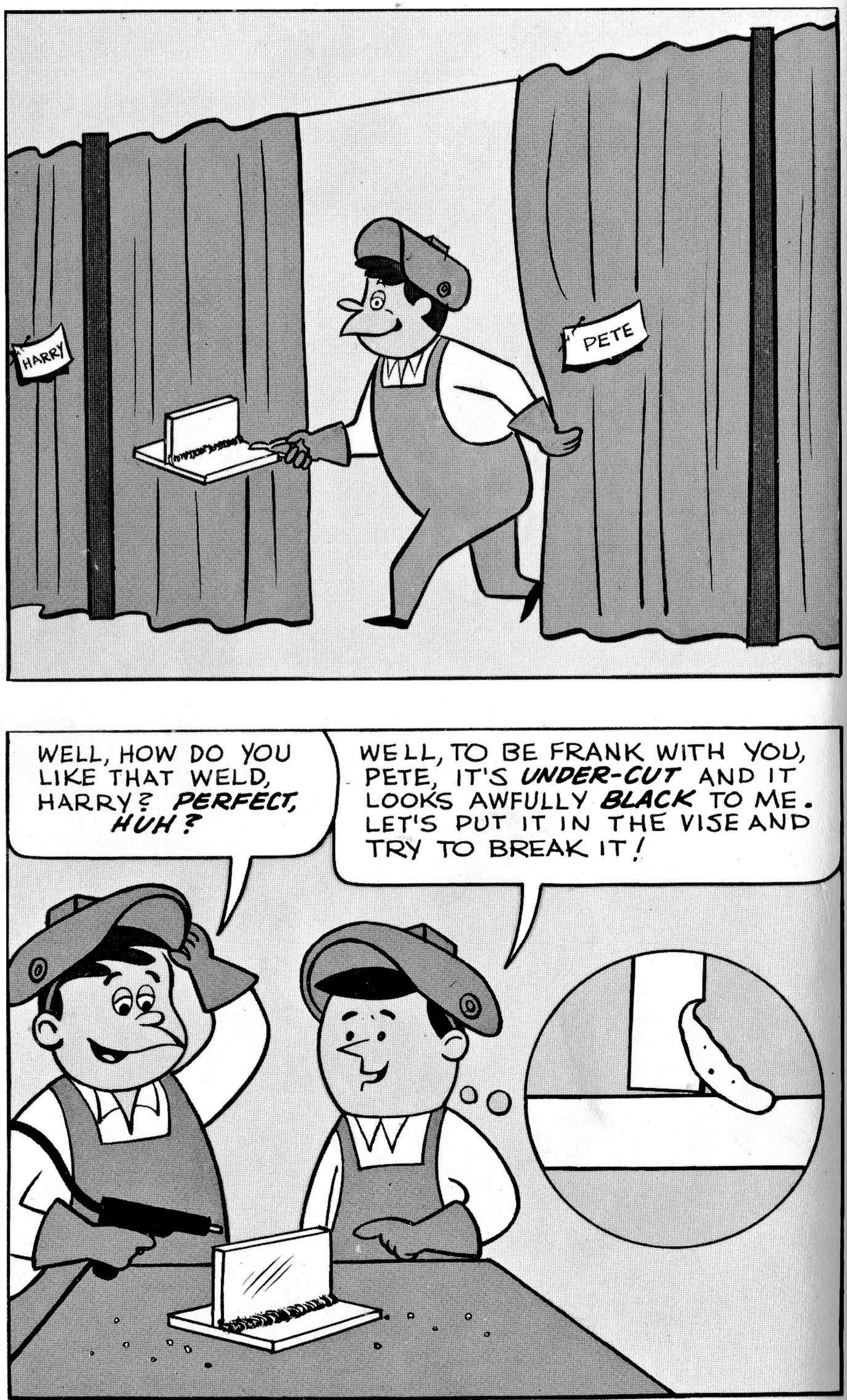
ojo!

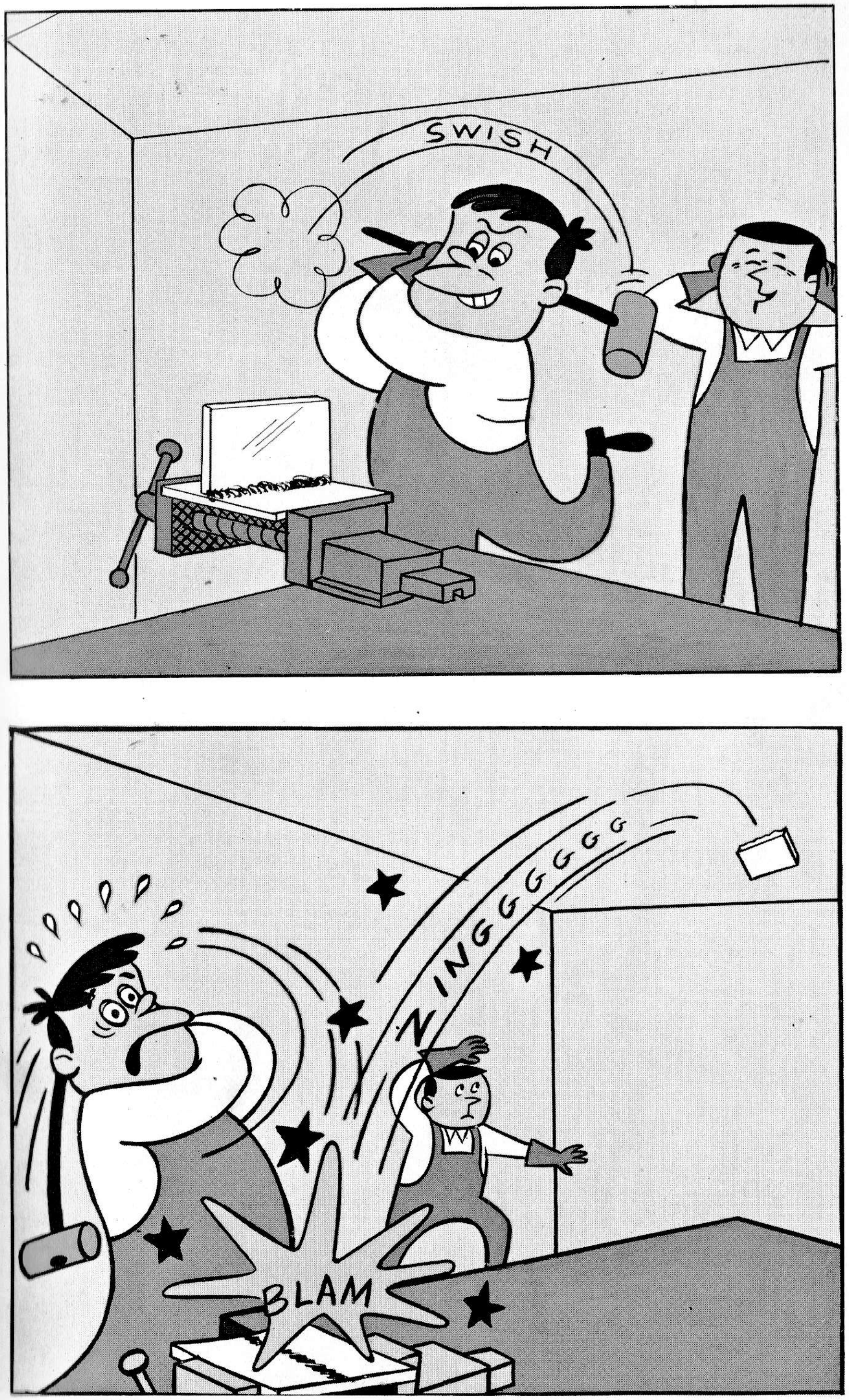

THIS IS 5086-H32, WHICH IS ONE QUARTER HARD, WITH 40,000 TENSILE, 28,000 YIELD, AND 6 TO 12 PERCENT ELONGATION BEFORE WELDING---
FOR WELDING THIS 3/8" THICK MATERIAL, WE WILL USE 1/16" DIAMETER TYPE 5356 FILLER WIRE, ABOUT 60 CUBIC FEET PER HOUR OF ARGON, 300 AMPERES, AND 26 VOLTS.
THE PLATES HAVE BEEN CLEANED, SO I'LL JUST MAKE A 5/16-INCH FILLET WELD TO SHOW YOU HOW IT'S DONE!


NOTICE THAT WE HAVE A FULL-SIZE FILLET, NO SURFACE DEFECTS AND NO UNDERCUT. A LITTLE PRACTICE, AND YOU CAN DO THE SAME!
THAT'S NOT SO HOT! LET'S PUT IT IN THE VISE AND BREAK IT!

I'LL BREAK IT!
I'LL BREAK IT!
BAM
BAM
"I'LL BREAK IT, I'LL BREAK IT!" WHO ARE YUH KIDDING, PETE? ANYONE CAN TELL THAT'S A GOOD WELD. NOW, WHY DON'T YOU TRY TO MAKE ONE LIKE IT?


AMPS.
HARRY
PETE

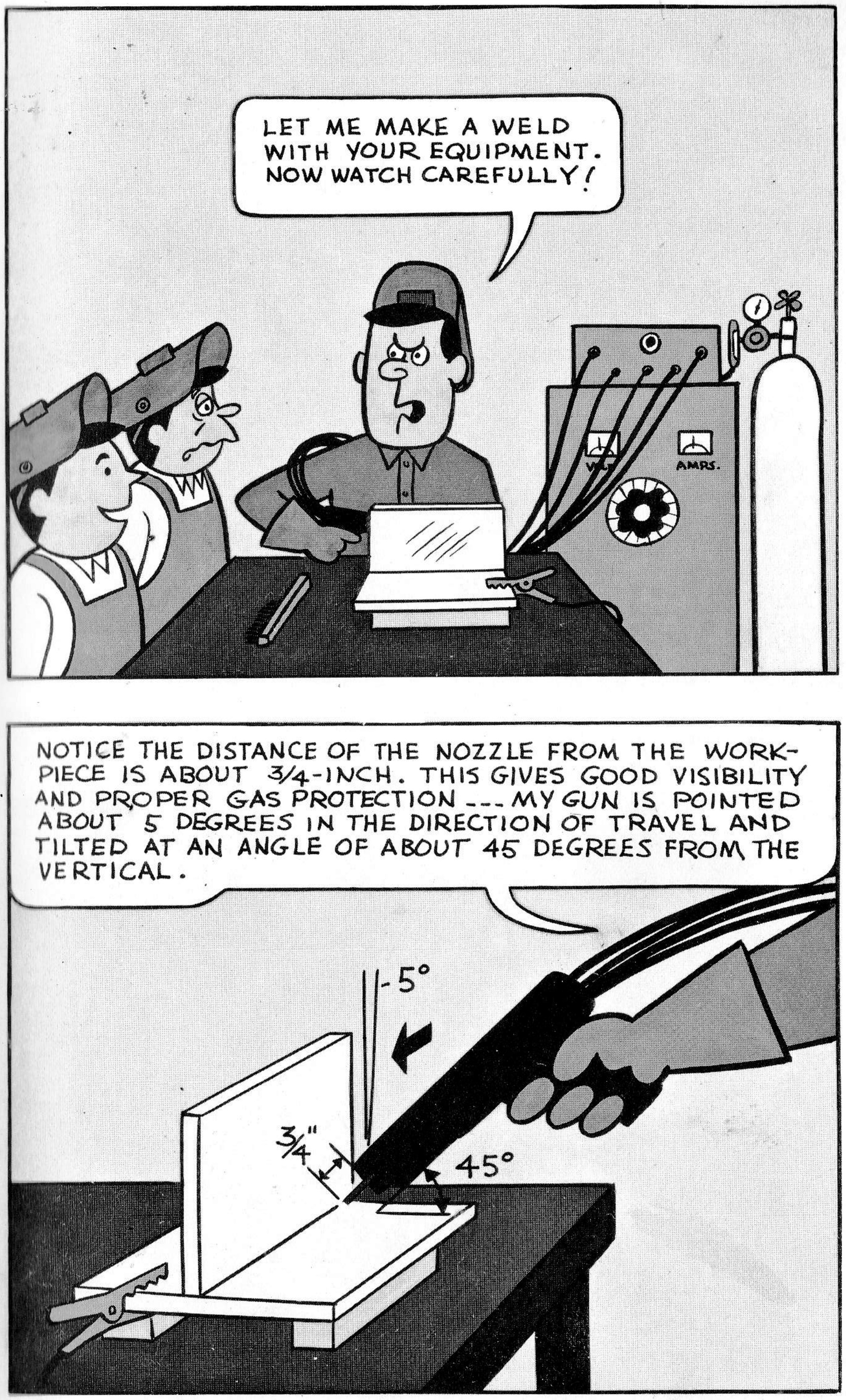

HARRY
PETE
WELL, HOW DO YOU LIKE THAT WELD, HARRY? PERFECT, HUH?
WELL, TO BE FRANK WITH YOU, PETE, IT'S UNDER-CUT AND IT LOOKS AWFULLY BLACK TO ME. LET'S PUT IT IN THE VISE AND TRY TO BREAK IT!

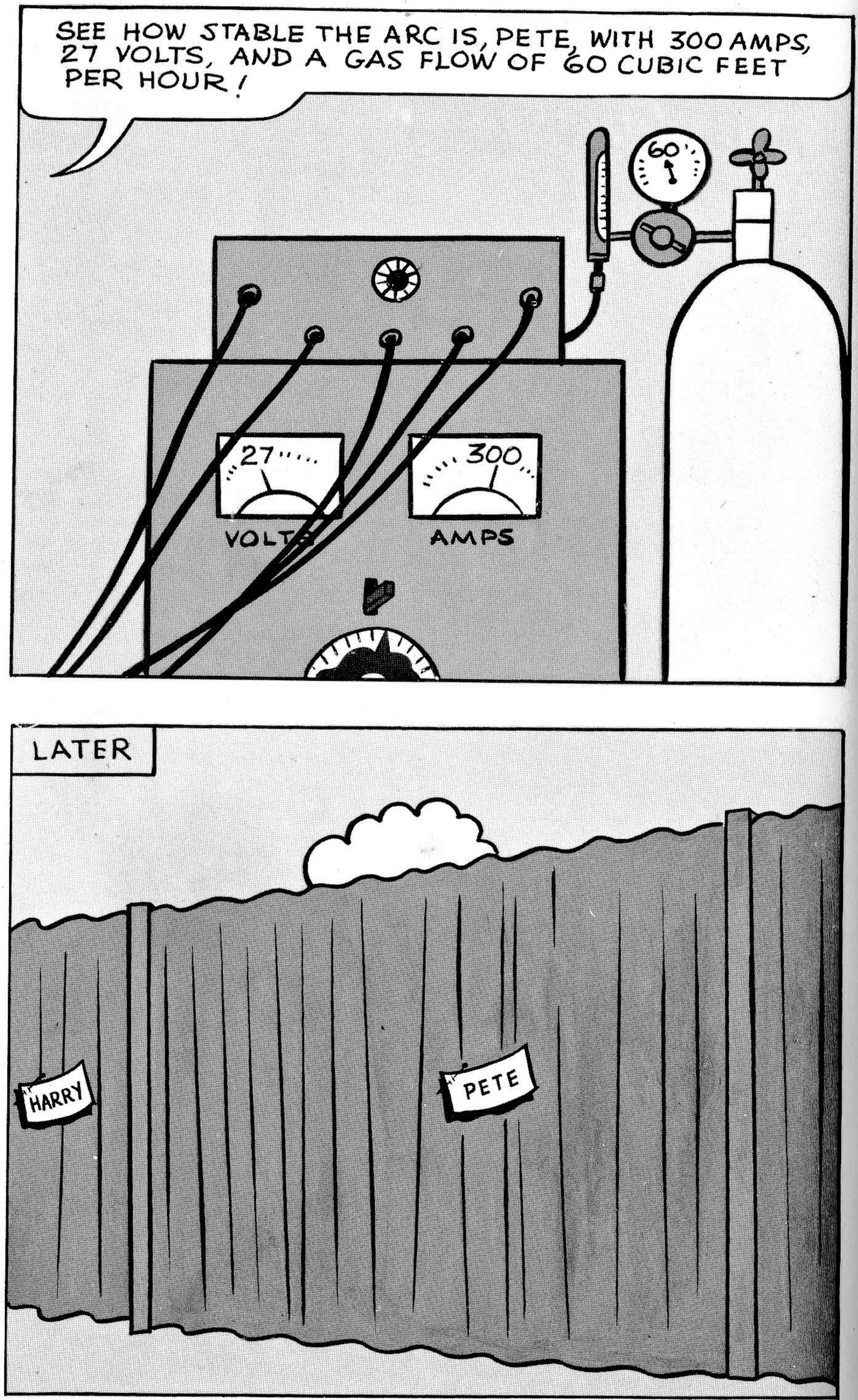

SWISH
BLAM
ZINGGGGGGG

WELL, HARRY, WHAT HAPPENED? THIS WELD DOESN'T LOOK VERY GOOD!
HARRY
PETE
DON'T LOOK AT ME, MR. JONES. THAT'S PETE'S WELD. WHAT'S THE MATTER WITH IT?
I HATE TO TELL YOU--- BUT I HAVE NEVER SEEN A WORSE FILLET WELD! IT'S *UNDERCUT,* IT'S LOADED WITH *POROSITY,* AND THERE'S *NO PENETRATION!*

PETE, HOW COULD YOU POSSIBLY MAKE A WELD LIKE THAT? WERE YOU HORSING AROUND OR DID YOU REALLY TRY TO MAKE A GOOD WELD?
WELL, AH-H-H-H! I GUESS IT JUST HAPPENED. THAT'S HOW YOU SAID TO DO IT.
MY HEAVENS! MY TEN-YEAR-OLD SON COULD--- OH! NEVER MIND. LET'S GO AND LOOK AT YOUR EQUIPMENT!

NOW, LET'S SEE. YOUR GAS FLOW IS-- **OH, GAD!** YOUR GAGE SHOWS **16 CUBIC FEET PER HOUR!** I SAID SET IT FOR **60!** THAT'S WHY YOUR WELD'S BLACK AND POROUS!
AMPS.
HOLD IT, HOLD IT! YOU'VE ONLY GOT **145 AMPS** ON YOUR POWER SUPPLY. HOW COULD YOU POSSIBLY WELD LIKE THAT? I SAID TO SET YOUR MACHINE AT ABOUT **300 AMPS!**
145
VOLTS
AMPS.

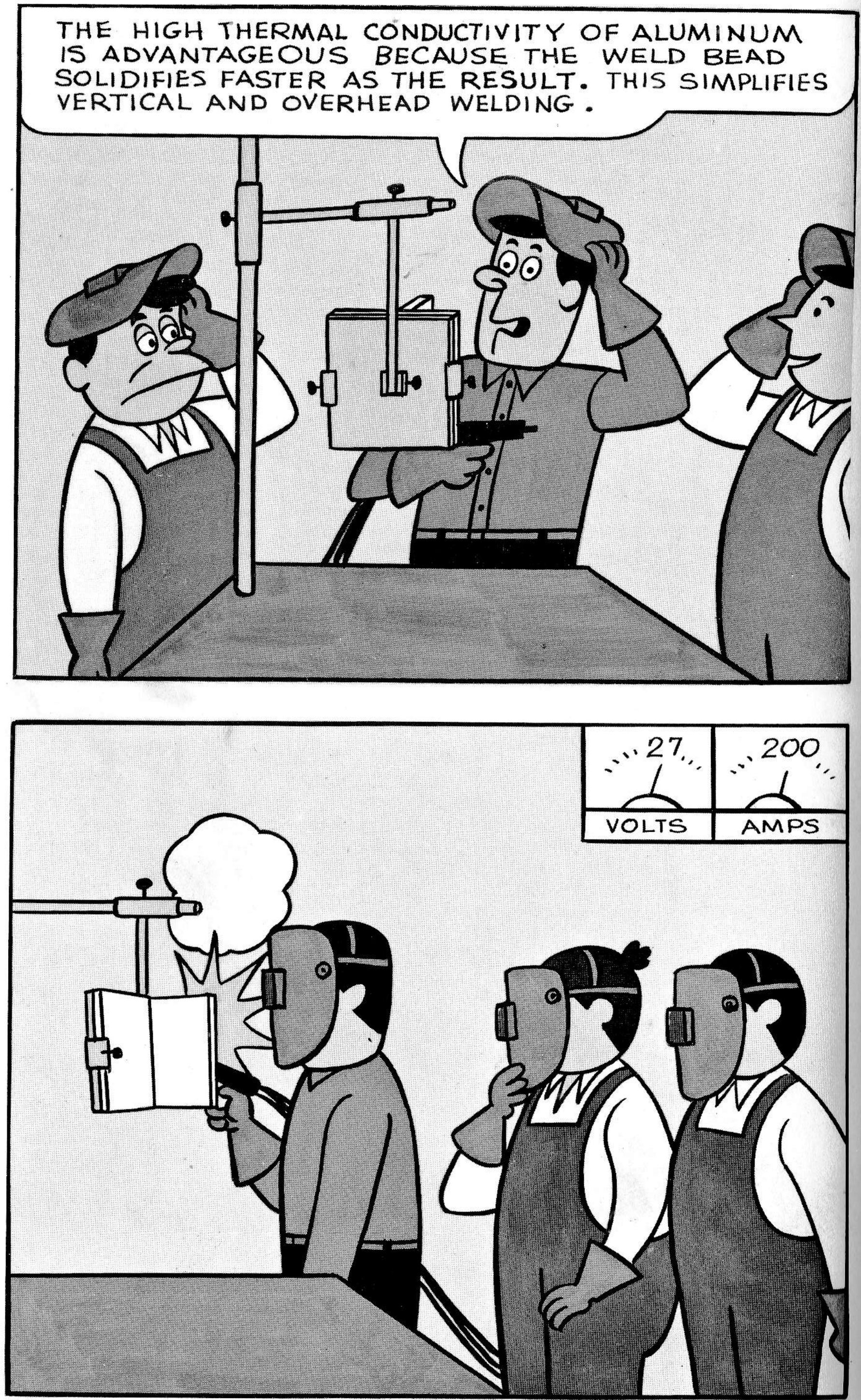

LET ME MAKE A WELD WITH YOUR EQUIPMENT. NOW WATCH CAREFULLY!
AMPS.
NOTICE THE DISTANCE OF THE NOZZLE FROM THE WORK-PIECE IS ABOUT 3/4-INCH. THIS GIVES GOOD VISIBILITY AND PROPER GAS PROTECTION --- MY GUN IS POINTED ABOUT 5 DEGREES IN THE DIRECTION OF TRAVEL AND TILTED AT AN ANGLE OF ABOUT 45 DEGREES FROM THE VERTICAL.
-5°
3/4"
45°

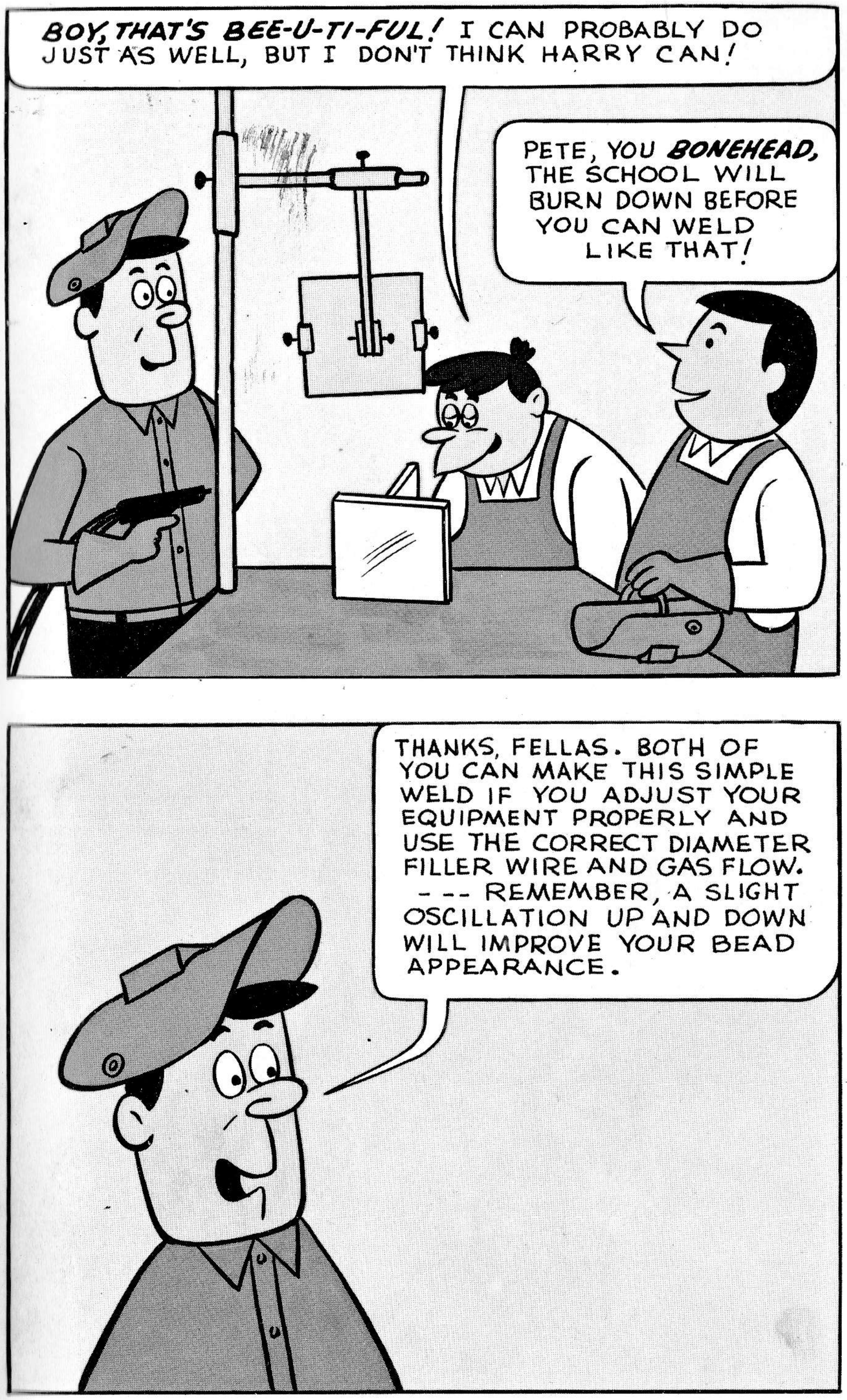

SEE HOW STABLE THE ARC IS, PETE, WITH 300 AMPS, 27 VOLTS, AND A GAS FLOW OF 60 CUBIC FEET PER HOUR!
60
27
VOLTS
300
AMPS
LATER
HARRY
PETE

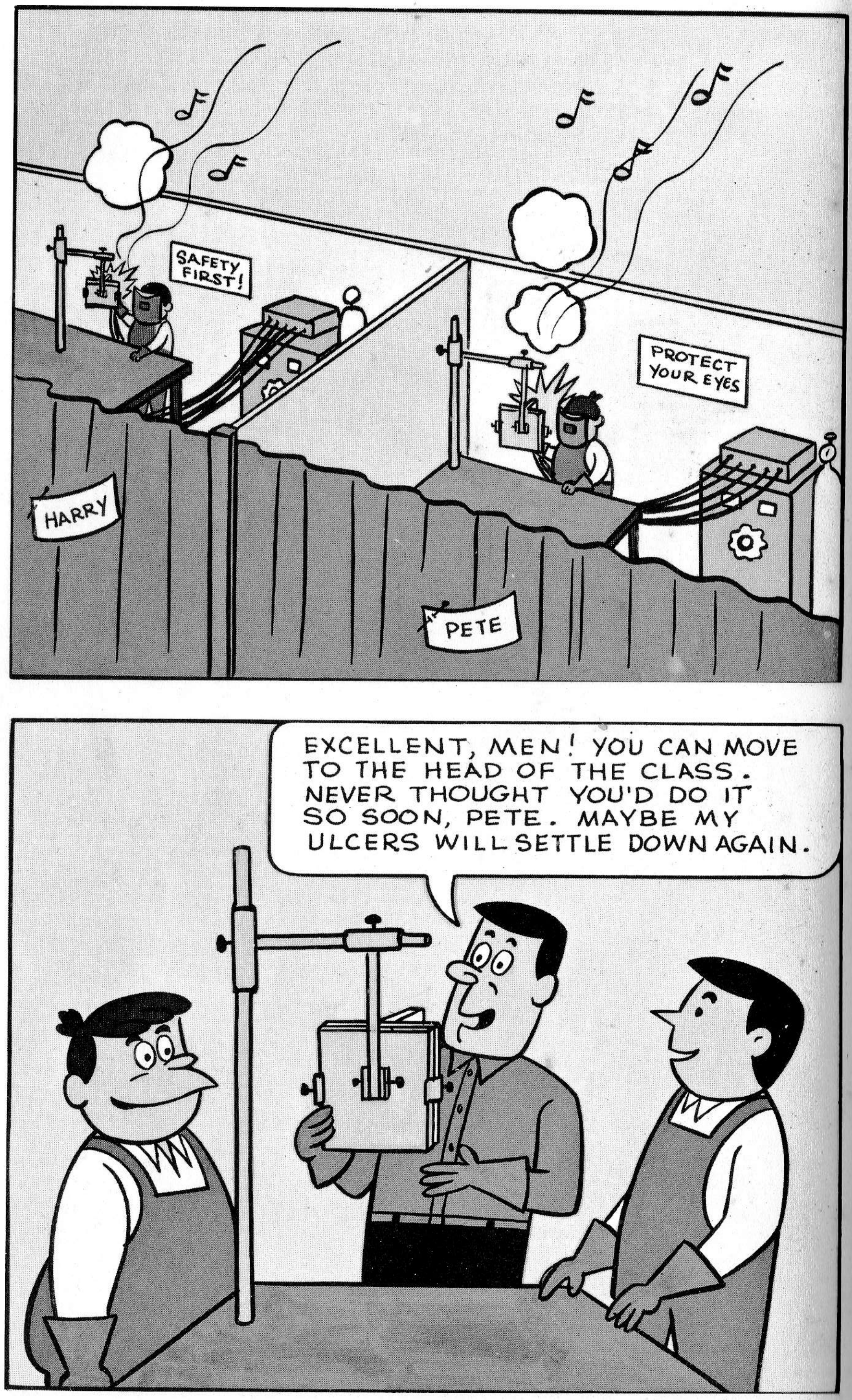
HARRY
PETE
WELL, WHAT DO YOU THINK NOW? GOOD, EH!
BOY! THAT'S A BIG IMPROVEMENT, PETE. WHAT DID YOU DO DIFFERENT?

I JUST ANALYZED THE SITUATION AND DECIDED TO INCREASE THE CURRENT AND GAS FLOW--- JUST GOOD COMMON SENSE!
YES, MR. DONAHUE, THEY'RE COMING ALONG SWELL. BELIEVE IT OR NOT, PETE JUST MADE A GOOD LOOK-ING FILLET WELD! THEY'LL BE BACK ON THE JOB IN NO TIME!

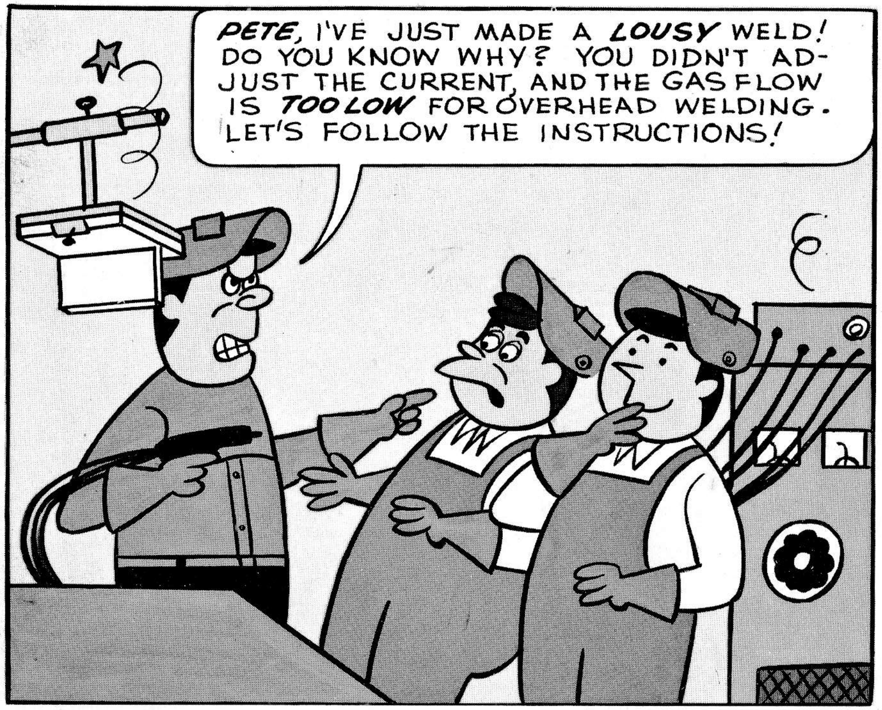
WELL, PETE, YOUR FILLET WELDS ARE FINALLY LOOKING GOOD. WE'LL HAVE TO MOVE ALONG---YOUR BOSS JUST CALLED AND WANTED TO KNOW WHEN YOU ARE GOING TO GRADUATE!
NEXT, I'LL DEMONSTRATE A VERTICAL AND OVERHEAD FILLET WELD. FOR MAXIMUM PENETRATION AND BEST QUALITY, THE VERTICAL WELD SHOULD BE MADE UPWARD WITH THE GUN POINTED IN THE DIRECTION OF TRAVEL--- THE PLATES ARE TACK WELDED IN POSITION AND PLACED IN THIS JIG READY FOR WELDING.


THE HIGH THERMAL CONDUCTIVITY OF ALUMINUM IS ADVANTAGEOUS BECAUSE THE WELD BEAD SOLIDIFIES FASTER AS THE RESULT. THIS SIMPLIFIES VERTICAL AND OVERHEAD WELDING.
27
200
VOLTS
AMPS


BOY, THAT'S BEE-U-TI-FUL! I CAN PROBABLY DO JUST AS WELL, BUT I DON'T THINK HARRY CAN!
PETE, YOU BONEHEAD, THE SCHOOL WILL BURN DOWN BEFORE YOU CAN WELD LIKE THAT!
THANKS, FELLAS. BOTH OF YOU CAN MAKE THIS SIMPLE WELD IF YOU ADJUST YOUR EQUIPMENT PROPERLY AND USE THE CORRECT DIAMETER FILLER WIRE AND GAS FLOW. --- REMEMBER, A SLIGHT OSCILLATION UP AND DOWN WILL IMPROVE YOUR BEAD APPEARANCE.


SAFETY FIRST!
PROTECT YOUR EYES
HARRY
PETE
EXCELLENT, MEN! YOU CAN MOVE TO THE HEAD OF THE CLASS. NEVER THOUGHT YOU'D DO IT SO SOON, PETE. MAYBE MY ULCERS WILL SETTLE DOWN AGAIN.

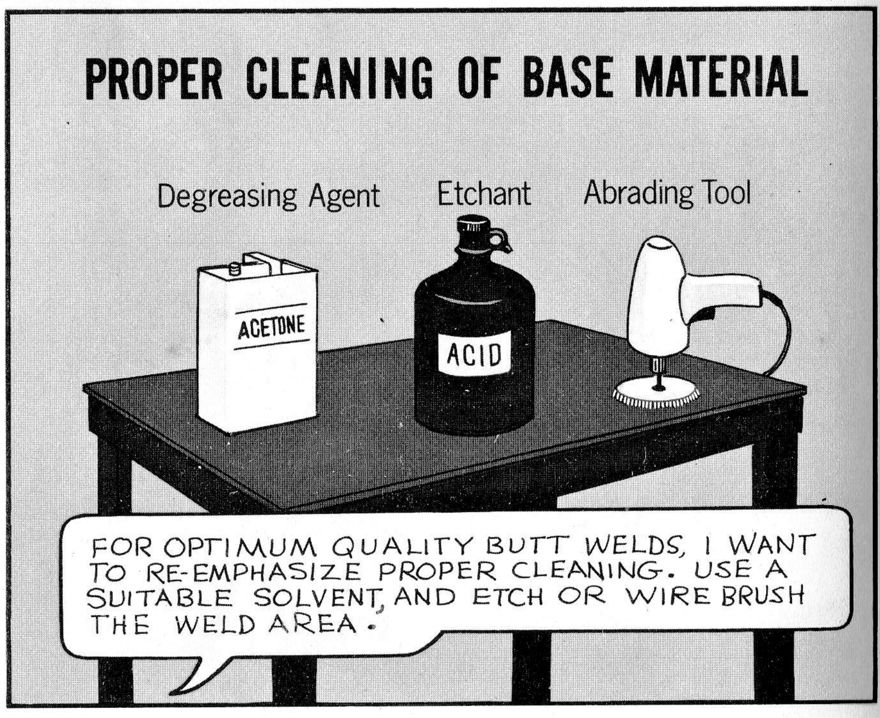
THIS OVERHEAD FILLET WELD IS EVEN EASIER TO MAKE THAN THE VERTICAL WELD. IF YOU'VE GOT THE EQUIPMENT ADJUSTED, PETE, I'LL DEMONSTRATE THE CORRECT TECHNIQUE FOR OVERHEAD WELDING.
VOLTS
AMPS
*?!! ∞ *


PETE, I'VE JUST MADE A LOUSY WELD! DO YOU KNOW WHY? YOU DIDN'T ADJUST THE CURRENT, AND THE GAS FLOW IS TOO LOW FOR OVERHEAD WELDING. LET'S FOLLOW THE INSTRUCTIONS!

27
VOLTS
220
AMPS

I'M - I'M SORRY MR. JONES. I DIDN'T THINK THE CURRENT WOULD MAKE MUCH DIFFERENCE!
OKAY, FELLAS! NO HARM DONE. IN FACT, IT POINTS UP A FINE LESSON. IF THE WELDING CONDITIONS AREN'T JUST RIGHT, EVEN THE BEST WELDOR CAN'T DO A GOOD JOB!
HERE WE GO AGAIN - GOOD OLD ALIBI PETE!

WELL, THAT TAKES CARE OF ALL YOUR FILLET WELDS. TOMORROW YOU BOYS START YOUR QUALIFICATION TESTS ON DOUBLE "V" BUTT WELDS MADE IN THE FLAT, VERTICAL, HORIZONTAL; AND OVERHEAD POSITIONS.

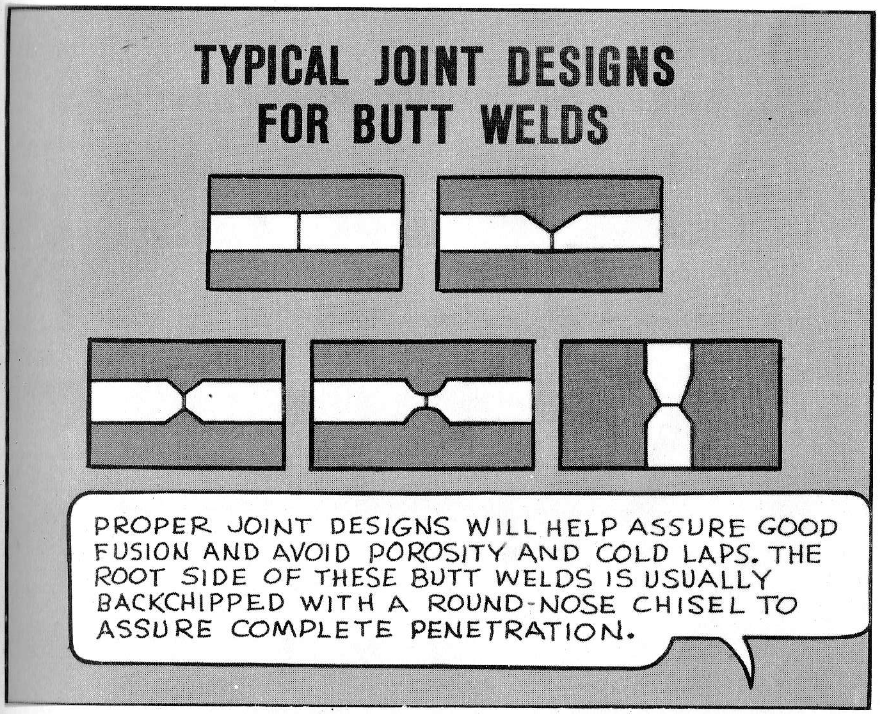


CORRECT FILLER MATERIAL FOR MIG WELDING

Alloy Combinations — 2nd part \ 1st part	6061 6063 6101 6151	5083 5456	5454	5086 5154	5052
5052	4043 5154	5356	5356 5554	5356 5154	5154 4043
5086 5154	5356 5154	5356	5356 5554	5356 5154	
5454	5356 5554	5356 5554	5554 5356		
5083 5456	5356	5356			
6061 6063 6101 6151	5154 4043				

Note: 1. 5183 or 5556 may be used in place of 5356.
2. 5254 may be used in place of 5154

REMEMBER, THE WRONG FILLER WIRE CAN CAUSE CORROSION, REDUCE MECHANICAL PROPERTIES, OR EVEN WORSE, RESULT IN WELD FAILURE!



CORRECT WELD CONDITIONS FOR BUTT WELDS

Stock Thickness inch	Position	Welding		Arc		Argon		Electrode	
		Passes	Speed inch/min Pass	Current amps dc	volts	Flow Rate cf/hr	Used per 100 feet cf	Diameter inch	Used per 100 feet lb
1/4	Flat	1	24	200	25	40	105	1/16	8
3/8	Flat	2	24	290	25	50	190	1/16	18
1/2	Flat	2	16	320	25-31	50	265	3/32	30
3/4	Flat	4	16	350	25-29	60	610	3/32	62
1	Flat	4	12	400	25-31	60	910	3/32	105

THE SECRET IN MAKING GOOD WELDS

CORRECT CURRENT

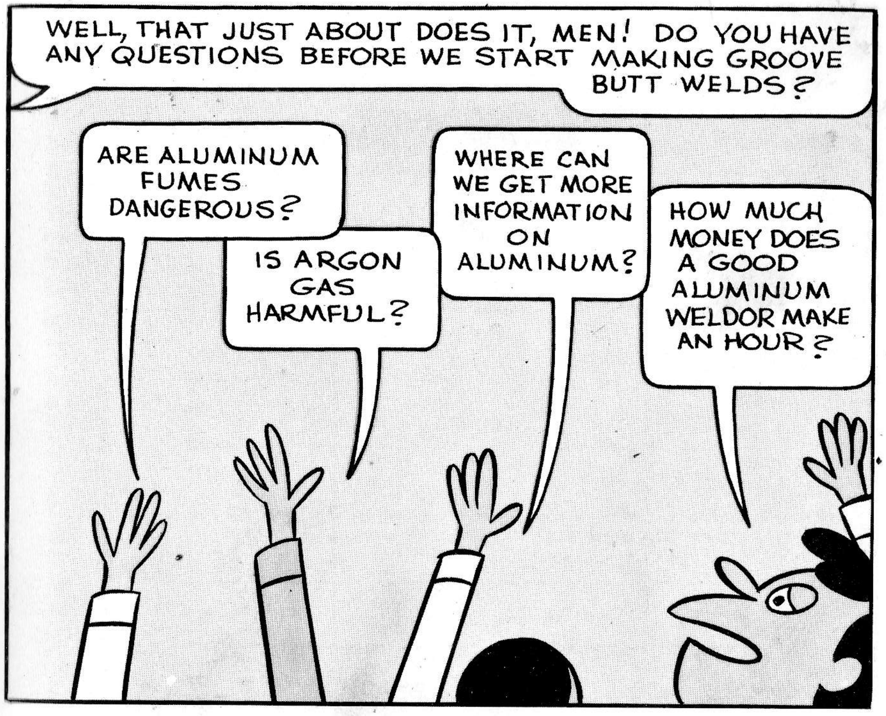
CORRECT VOLTAGE

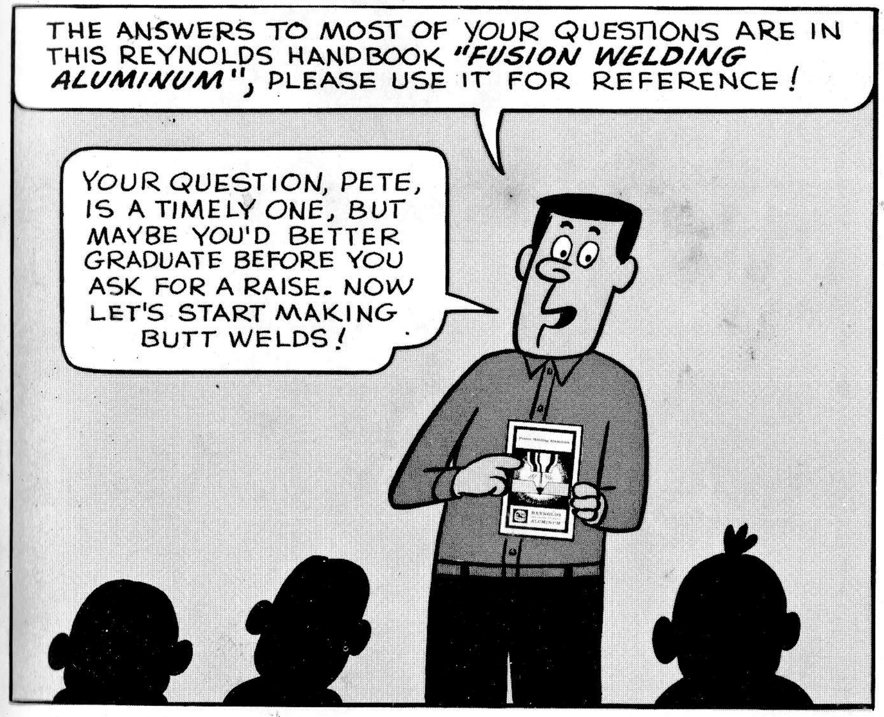
CORRECT GAS FLOW

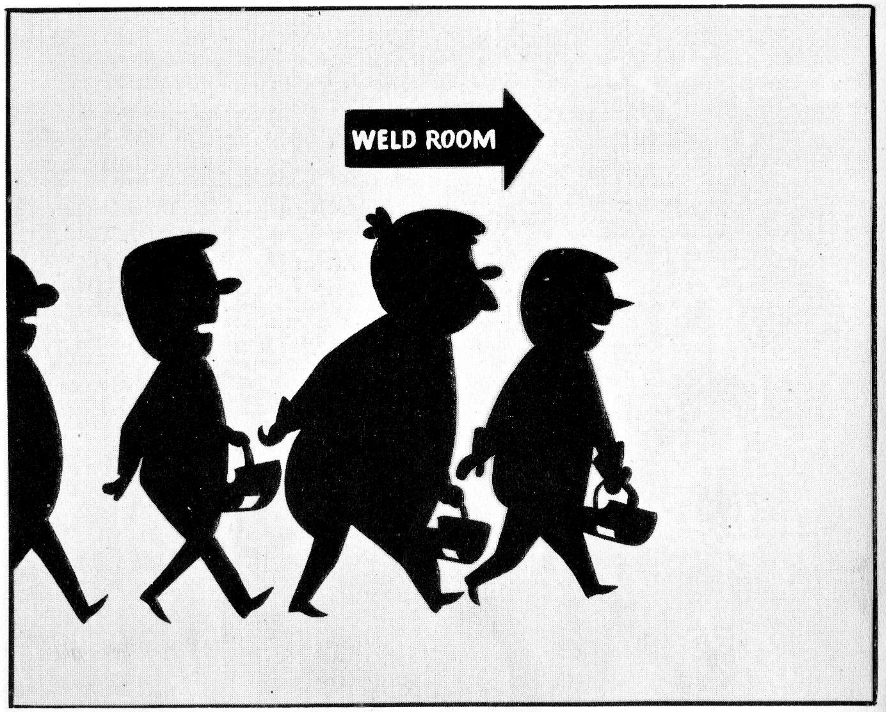
CORRECT FILLER WIRE

CORRECT CLEANING

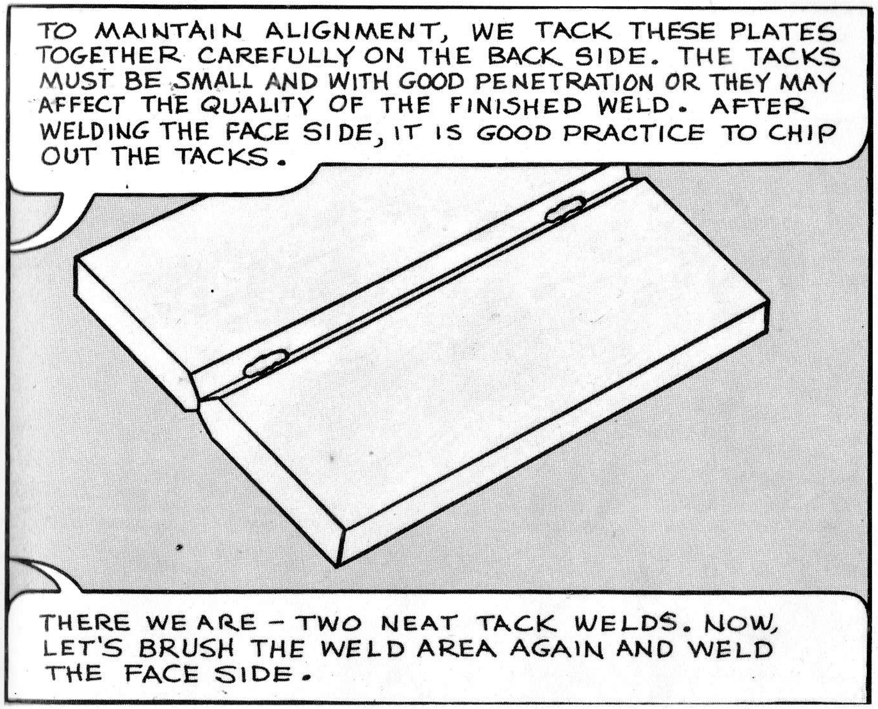
CORRECT JOINT DESIGN

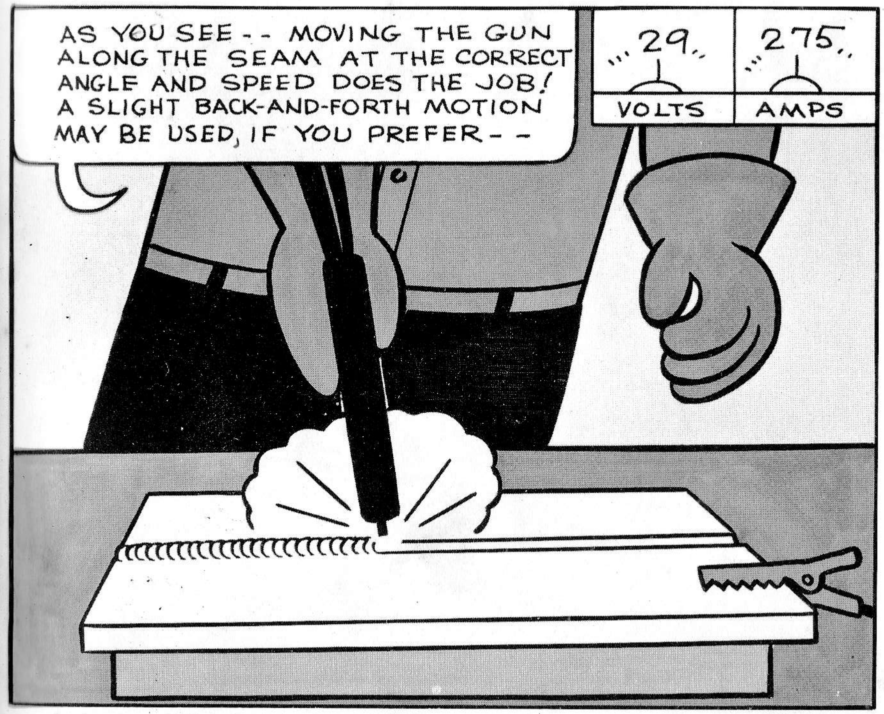


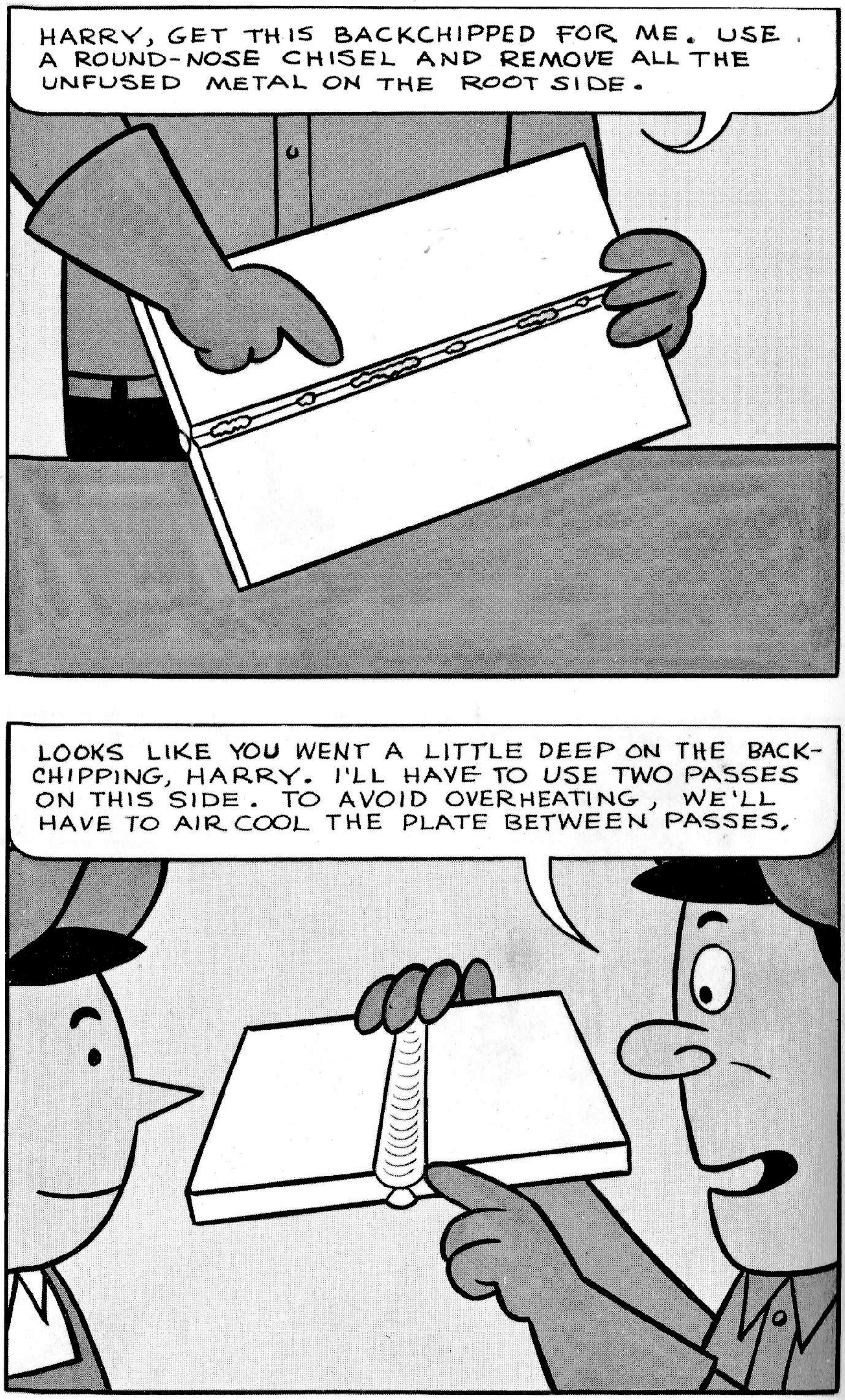



WELD ROOM

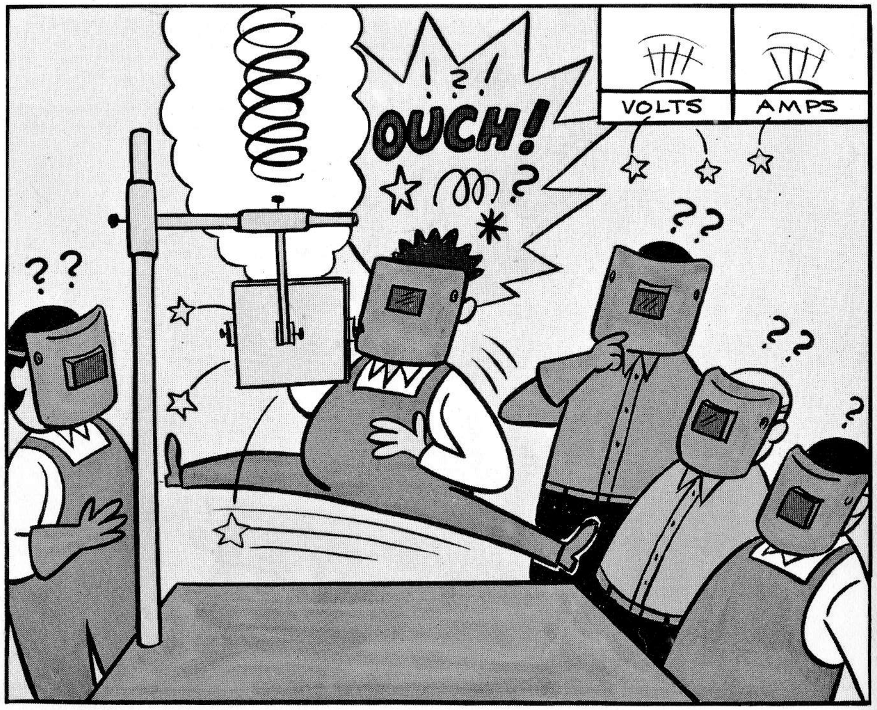
TO SAVE TIME, I WILL DEMONSTRATE BUTT WELDING IN THE FLAT, VERTICAL, HORIZONTAL AND OVERHEAD POSITIONS. HARRY, CAN YOU ADJUST THE EQUIPMENT FOR FLAT POSITION WELDING?

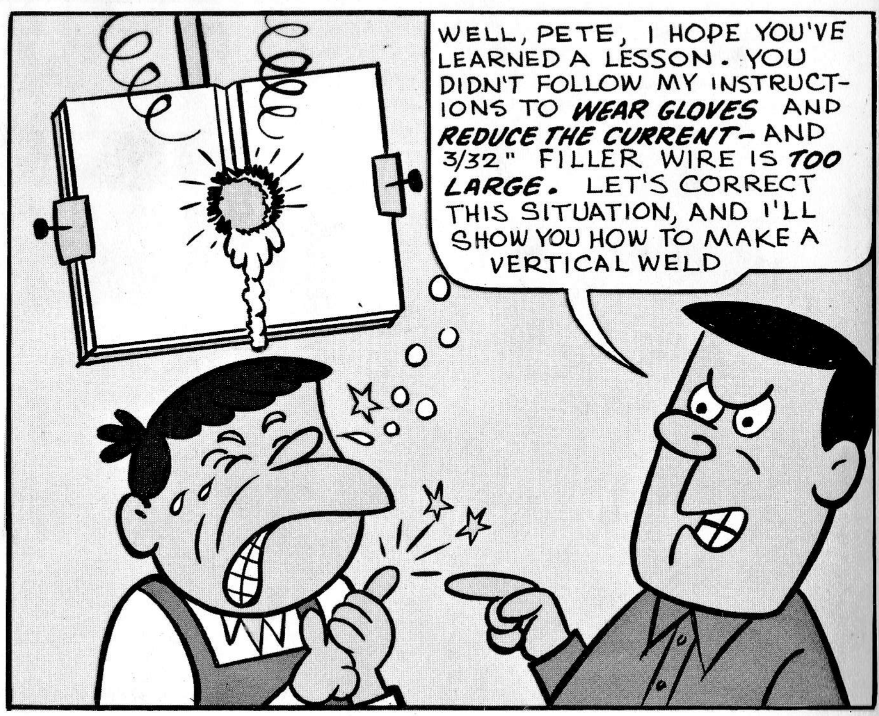

TO MAINTAIN ALIGNMENT, WE TACK THESE PLATES TOGETHER CAREFULLY ON THE BACK SIDE. THE TACKS MUST BE SMALL AND WITH GOOD PENETRATION OR THEY MAY AFFECT THE QUALITY OF THE FINISHED WELD. AFTER WELDING THE FACE SIDE, IT IS GOOD PRACTICE TO CHIP OUT THE TACKS.
THERE WE ARE - TWO NEAT TACK WELDS. NOW, LET'S BRUSH THE WELD AREA AGAIN AND WELD THE FACE SIDE.

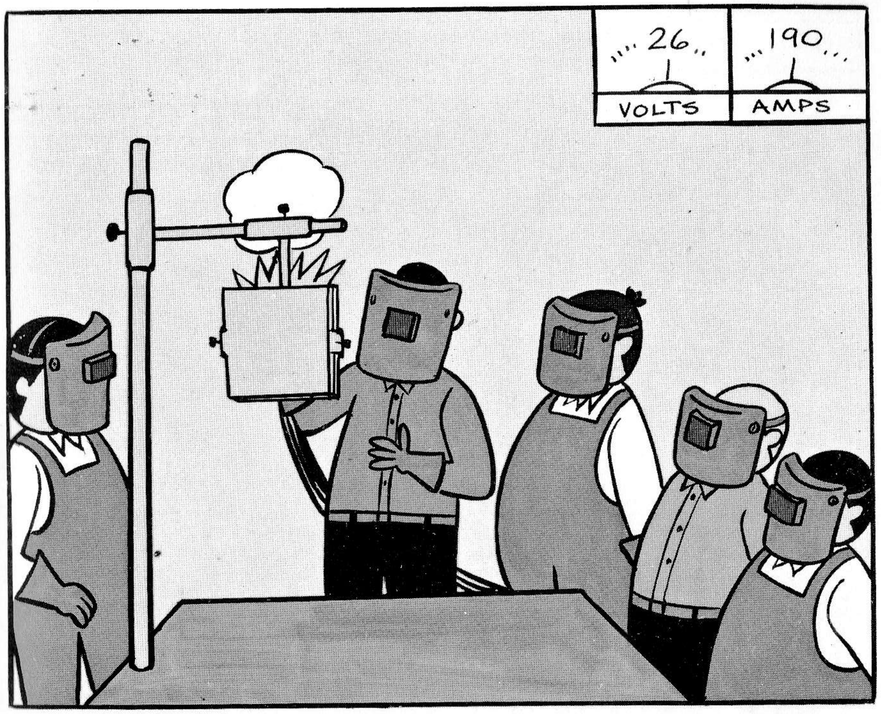

AS YOU SEE -- MOVING THE GUN ALONG THE SEAM AT THE CORRECT ANGLE AND SPEED DOES THE JOB! A SLIGHT BACK-AND-FORTH MOTION MAY BE USED, IF YOU PREFER --
29
VOLTS
275
AMPS

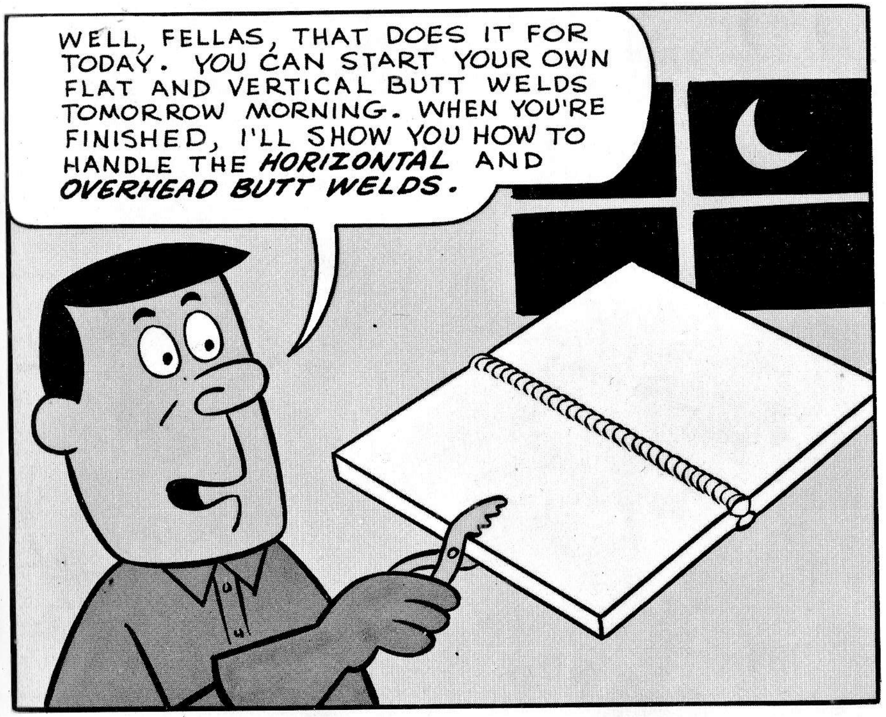

HARRY, GET THIS BACKCHIPPED FOR ME. USE A ROUND-NOSE CHISEL AND REMOVE ALL THE UNFUSED METAL ON THE ROOT SIDE.
LOOKS LIKE YOU WENT A LITTLE DEEP ON THE BACK-CHIPPING, HARRY. I'LL HAVE TO USE TWO PASSES ON THIS SIDE. TO AVOID OVERHEATING, WE'LL HAVE TO AIR COOL THE PLATE BETWEEN PASSES.

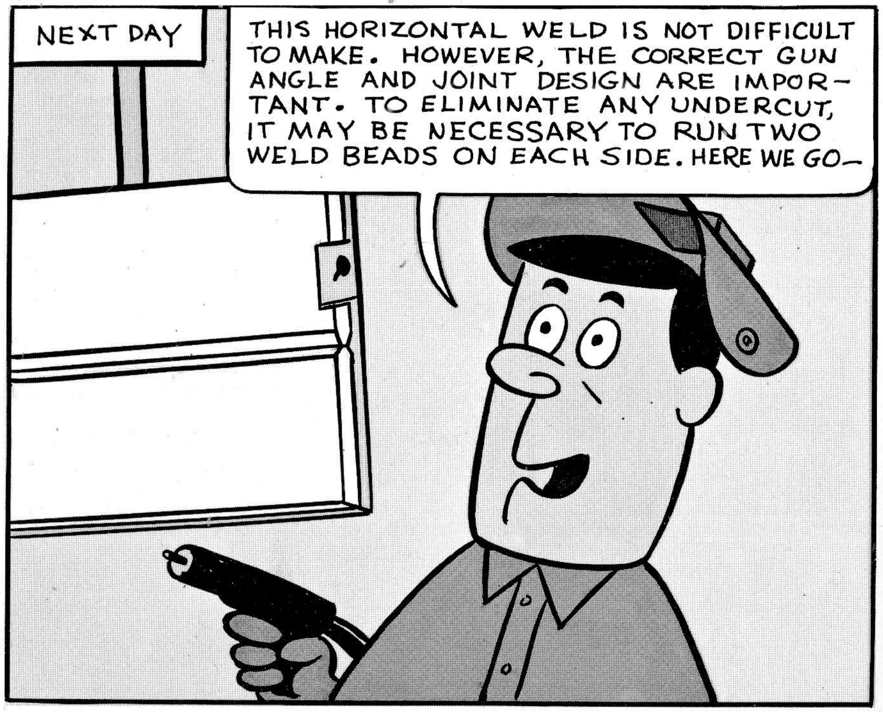
WELL, THAT TAKES CARE OF THE FLAT POSITION. BUTT WELDS IN OTHER POSITIONS ARE EQUALLY SIMPLE, IF YOU ADJUST YOUR EQUIPMENT PROPERLY. FOR BEST RESULTS, USE LOWER CURRENTS AND 1/16" OR 3/64" DIAMETER FILLER WIRE.
CROSS SECTION FINISHED WELD
THESE PLATES HAVE BEEN TACK WELDED AND CLEANED - READY FOR A VERTICAL WELD. NOW, WHO WOULD LIKE TO VOLUNTEER? OKAY, PETE, YOU TRY IT!

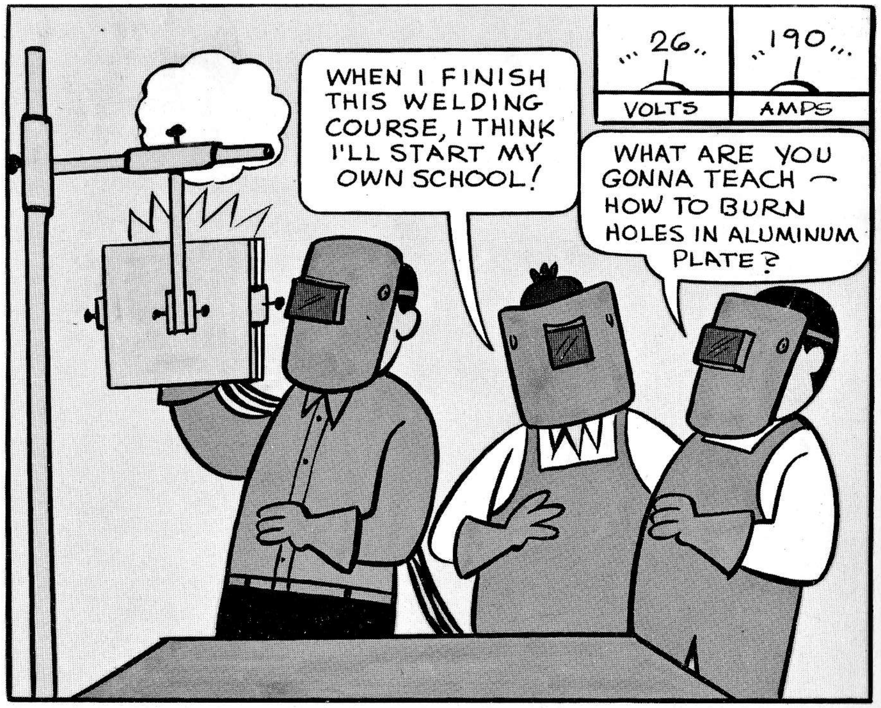

!?!
OUCH!
VOLTS
AMPS

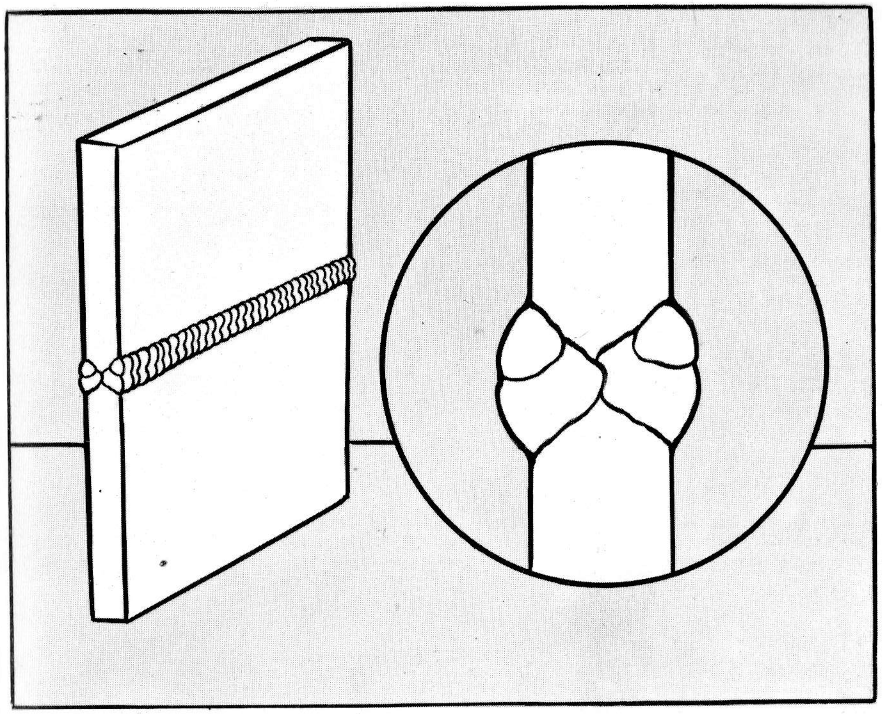

WELL, PETE, I HOPE YOU'VE LEARNED A LESSON. YOU DIDN'T FOLLOW MY INSTRUCTIONS TO **WEAR GLOVES** AND **REDUCE THE CURRENT**– AND 3/32" FILLER WIRE IS **TOO LARGE**. LET'S CORRECT THIS SITUATION, AND I'LL SHOW YOU HOW TO MAKE A VERTICAL WELD

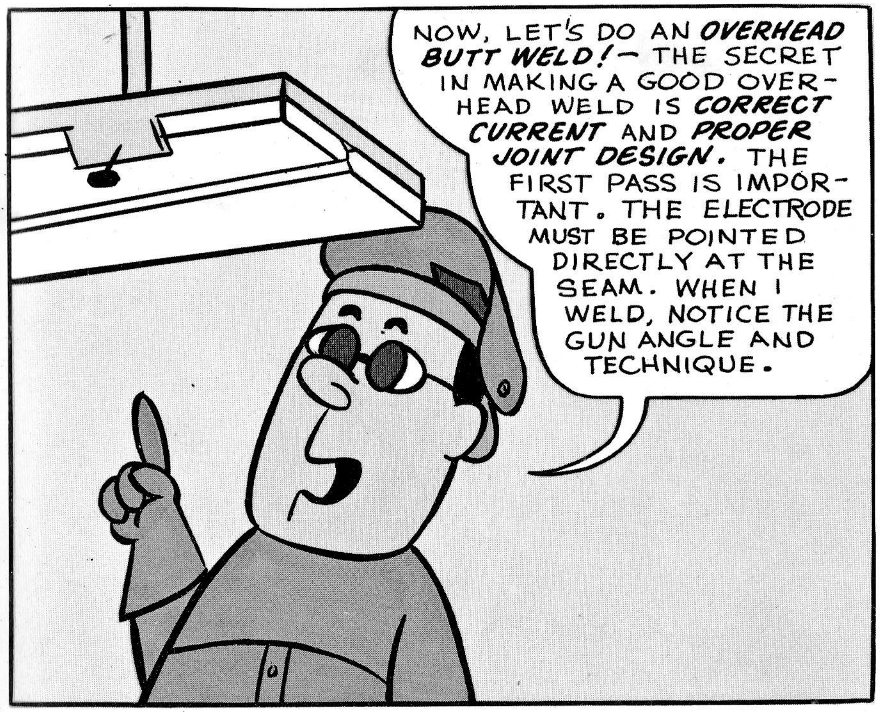

26
190
VOLTS
AMPS

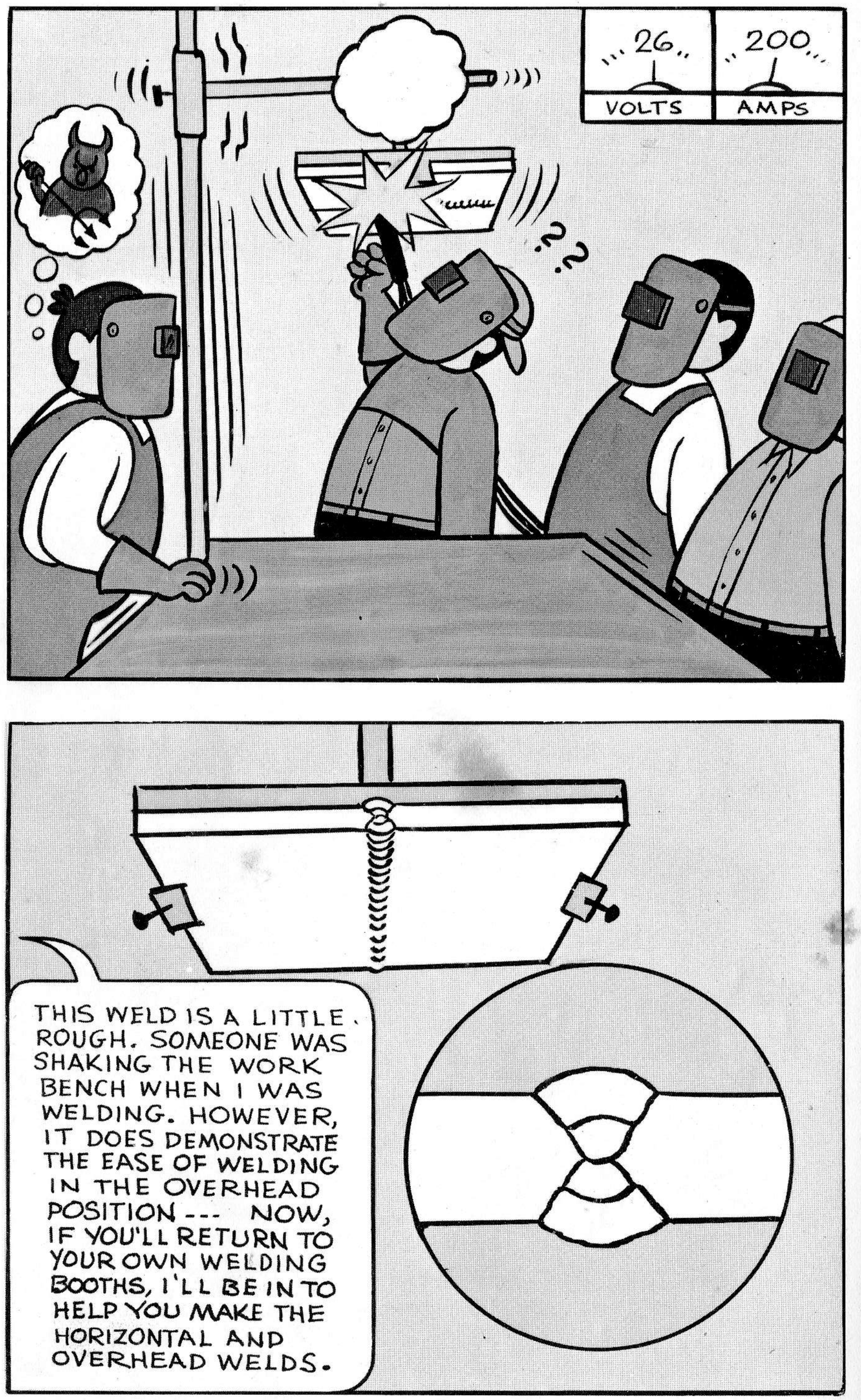

WELL, FELLAS, THAT DOES IT FOR TODAY. YOU CAN START YOUR OWN FLAT AND VERTICAL BUTT WELDS TOMORROW MORNING. WHEN YOU'RE FINISHED, I'LL SHOW YOU HOW TO HANDLE THE **HORIZONTAL** AND **OVERHEAD BUTT WELDS**.


NEXT DAY
THIS HORIZONTAL WELD IS NOT DIFFICULT TO MAKE. HOWEVER, THE CORRECT GUN ANGLE AND JOINT DESIGN ARE IMPORTANT. TO ELIMINATE ANY UNDERCUT, IT MAY BE NECESSARY TO RUN TWO WELD BEADS ON EACH SIDE. HERE WE GO—

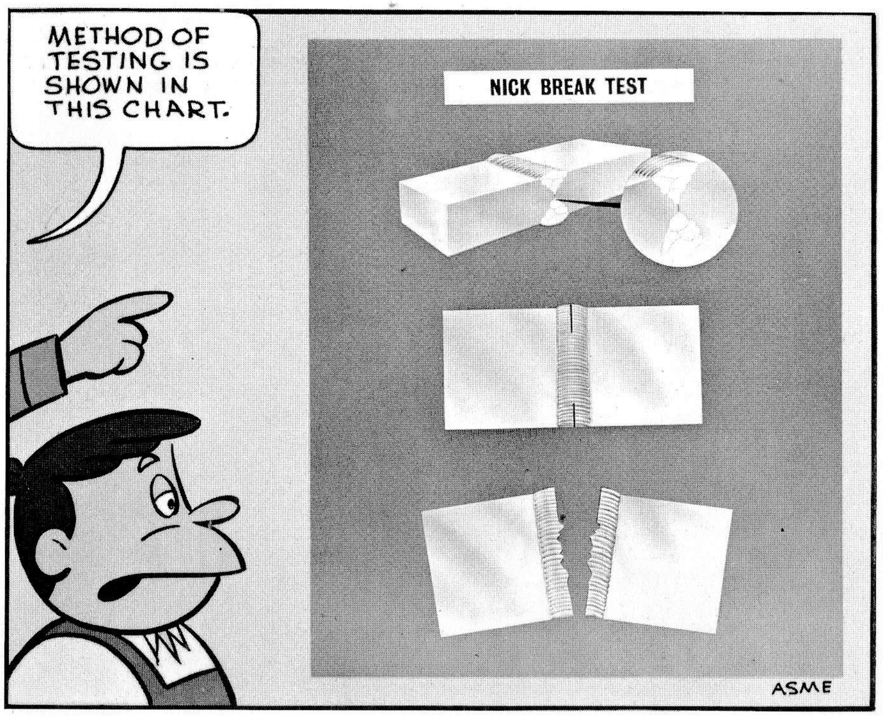

...26...
...190...
VOLTS
AMPS
WHEN I FINISH THIS WELDING COURSE, I THINK I'LL START MY OWN SCHOOL!
WHAT ARE YOU GONNA TEACH — HOW TO BURN HOLES IN ALUMINUM PLATE?



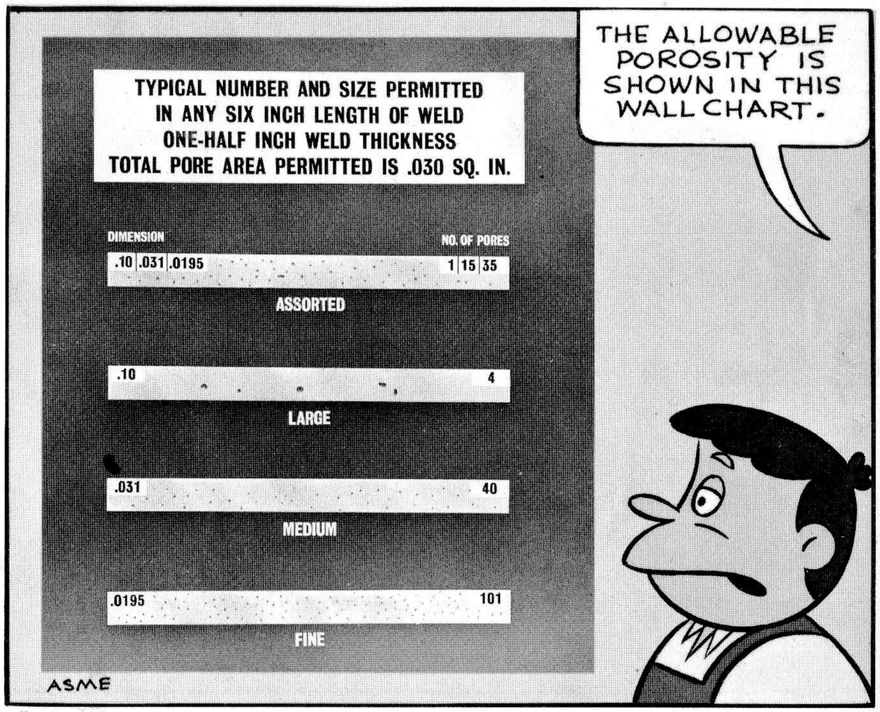

NOW, LET'S DO AN ***OVERHEAD BUTT WELD!*** — THE SECRET IN MAKING A GOOD OVERHEAD WELD IS ***CORRECT CURRENT*** AND ***PROPER JOINT DESIGN.*** THE FIRST PASS IS IMPORTANT. THE ELECTRODE MUST BE POINTED DIRECTLY AT THE SEAM. WHEN I WELD, NOTICE THE GUN ANGLE AND TECHNIQUE.


26
200
VOLTS
AMPS
??
THIS WELD IS A LITTLE ROUGH. SOMEONE WAS SHAKING THE WORK BENCH WHEN I WAS WELDING. HOWEVER, IT DOES DEMONSTRATE THE EASE OF WELDING IN THE OVERHEAD POSITION --- NOW, IF YOU'LL RETURN TO YOUR OWN WELDING BOOTHS, I'LL BE IN TO HELP YOU MAKE THE HORIZONTAL AND OVERHEAD WELDS.

LATER
PETE, YOU'RE THE LAST ONE TO FINISH YOUR OVERHEAD WELD! DO YOU WANT ME TO DO ONE MORE FOR YOU?
OH, NOT ME! I'VE GOT A PERFECT WELD THIS TIME. COMPLETELY PENETRATED!
WELL, YOU CAN'T TELL BY LOOKING AT THE WELD — LET'S SECTION IT AND MAKE A NICK BREAK TEST. THIS WILL SAVE X-RAY COSTS.



(See Page 89)



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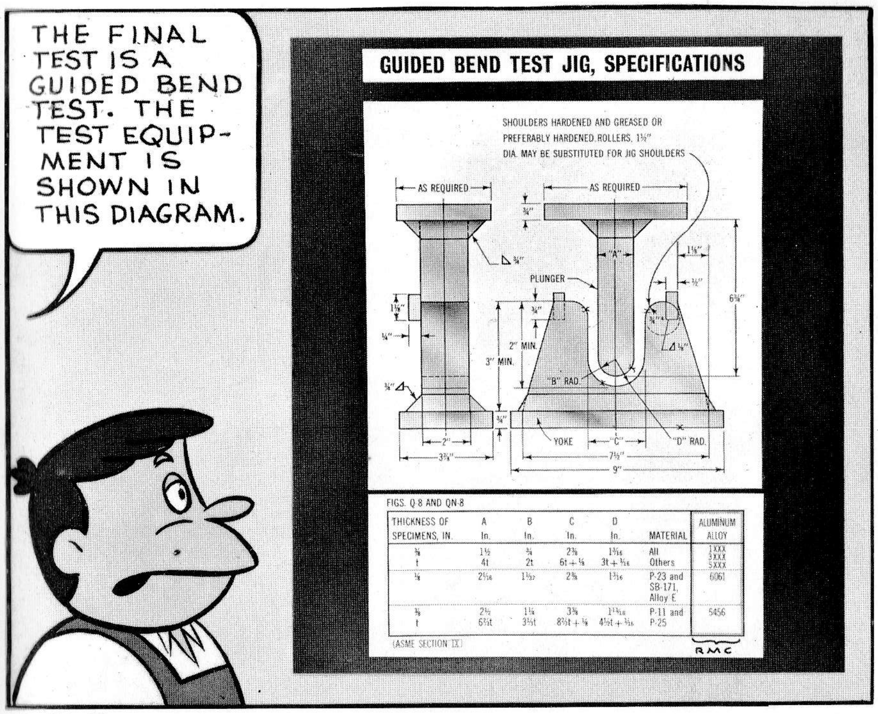

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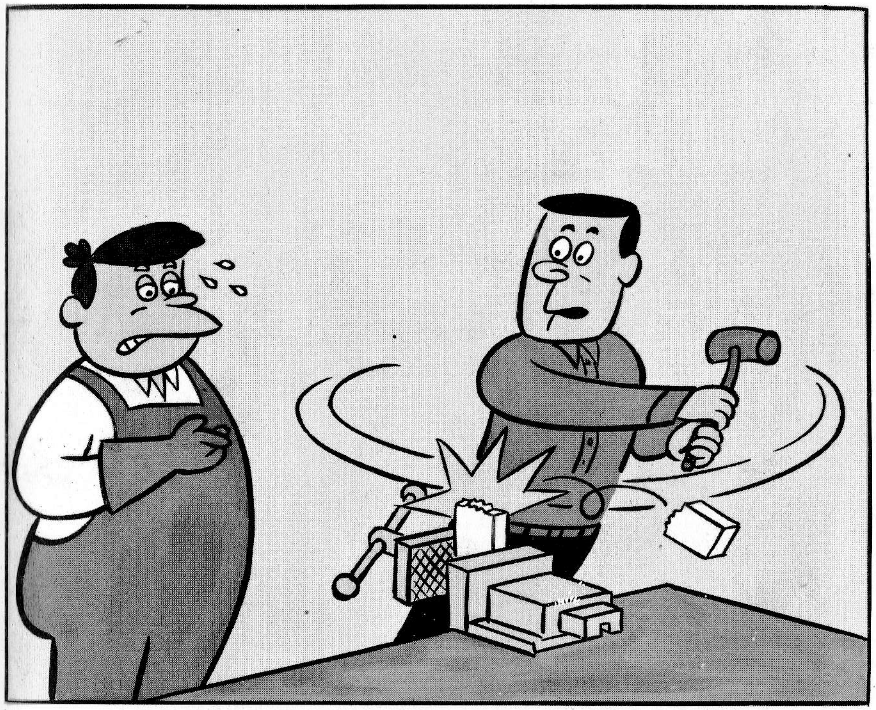
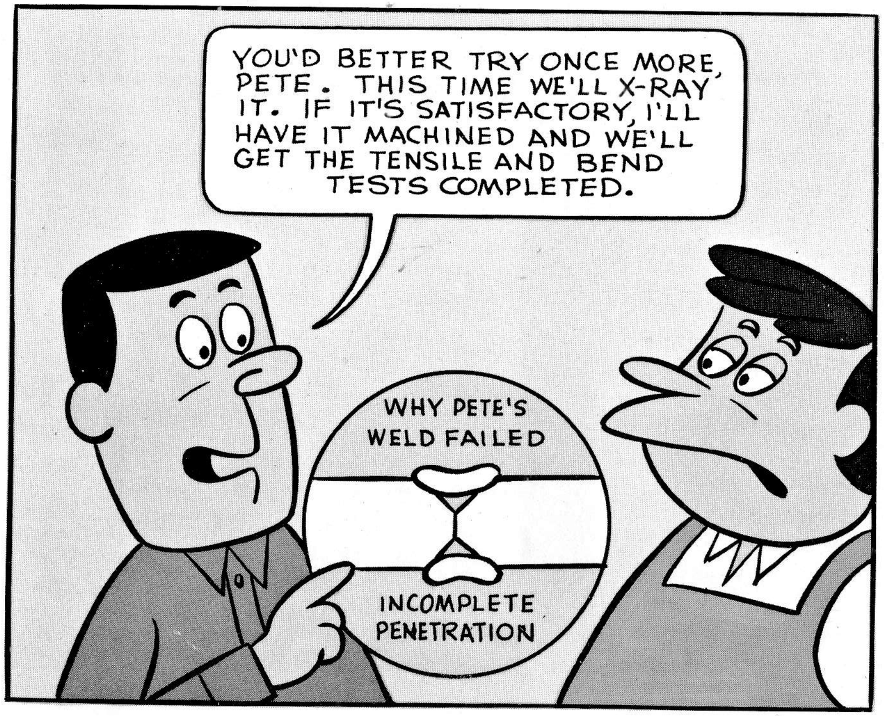
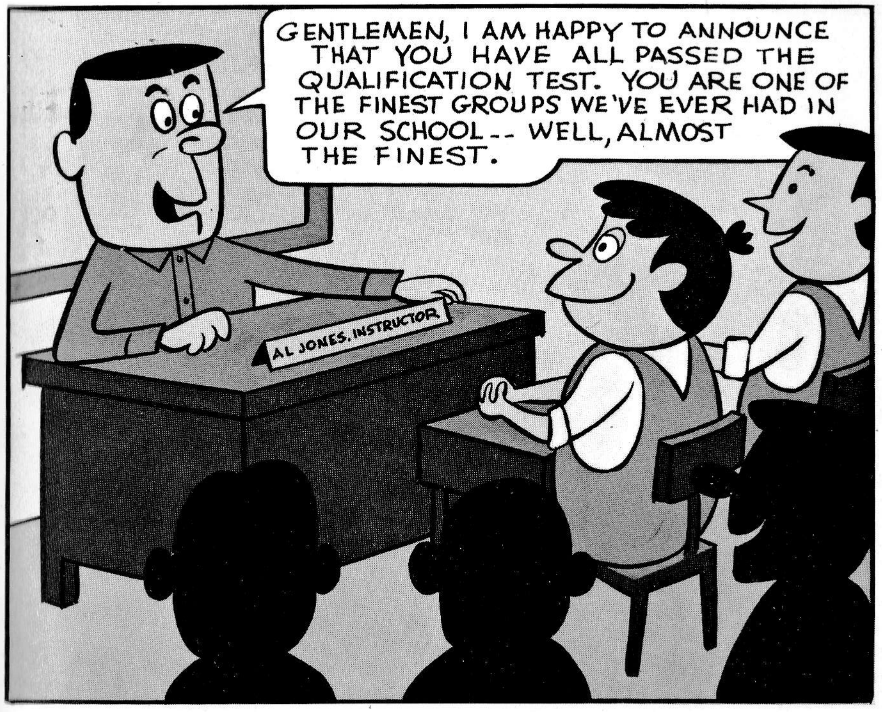
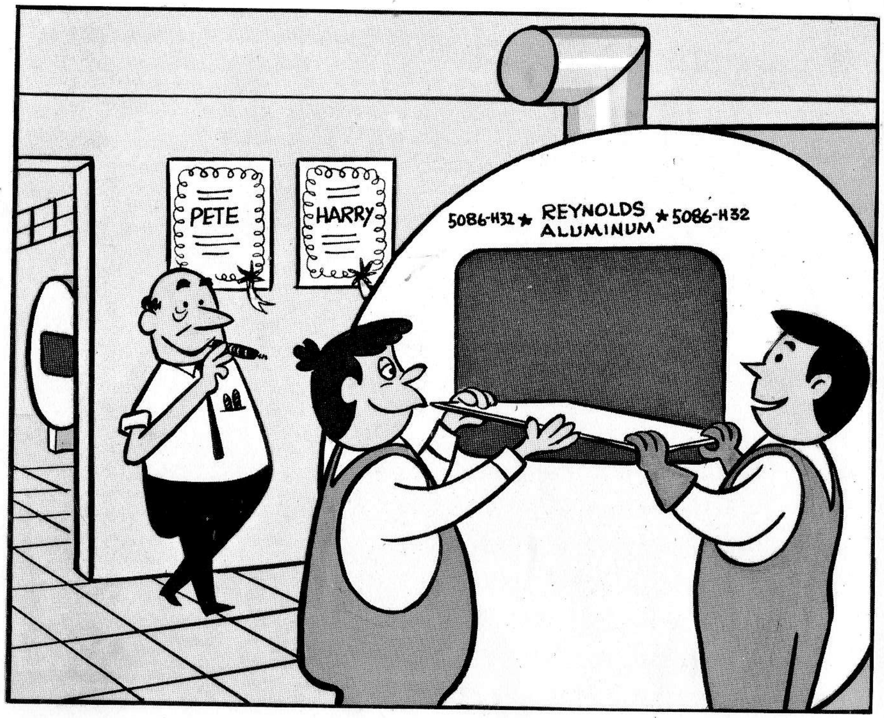


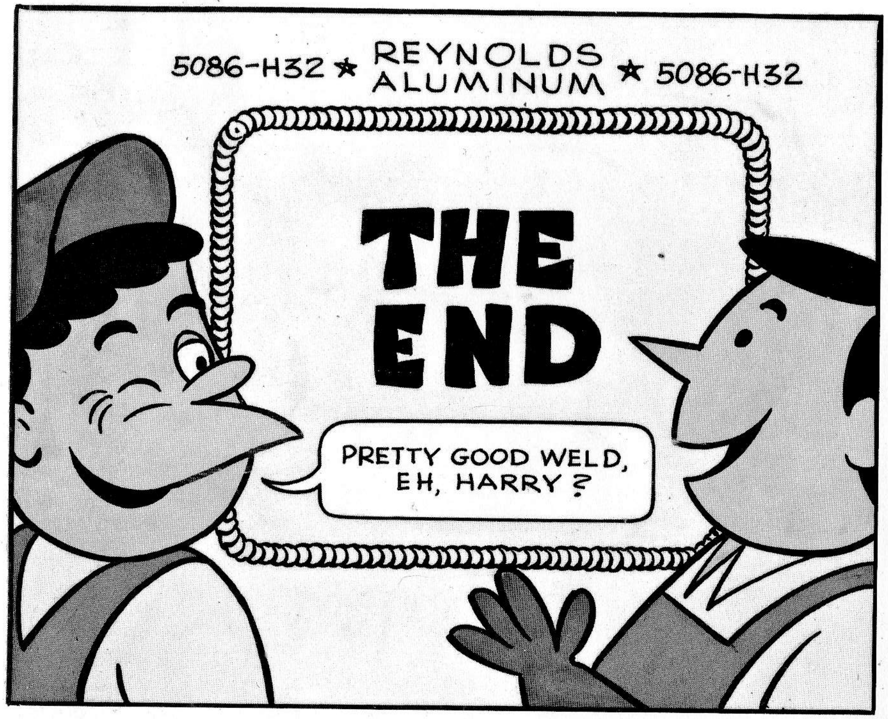

YOU'D BETTER TRY ONCE MORE, PETE. THIS TIME WE'LL X-RAY IT. IF IT'S SATISFACTORY, I'LL HAVE IT MACHINED AND WE'LL GET THE TENSILE AND BEND TESTS COMPLETED.
WHY PETE'S WELD FAILED
INCOMPLETE PENETRATION

LATER
HURRAH! LOOKS LIKE PETE FINALLY MADE IT!
WELL, WHO COULDN'T, AFTER SIX TRYS?


GENTLEMEN, I AM HAPPY TO ANNOUNCE THAT YOU HAVE ALL PASSED THE QUALIFICATION TEST. YOU ARE ONE OF THE FINEST GROUPS WE'VE EVER HAD IN OUR SCHOOL -- WELL, ALMOST THE FINEST.
AL JONES, INSTRUCTOR

IT GIVES ME GREAT PLEASURE TO PRESENT YOU WITH THIS CERTIFICATE OF GRADUATION. IF I CAN HELP ANY OF YOU IN THE FUTURE, PLEASE CALL ME!





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APPENDIX

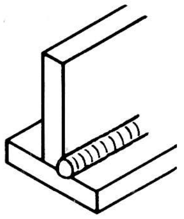
Table 1—FILLER METAL FOR GAS METAL ARC (MIG) AND GAS TUNGSTEN ARC (TIG)

Recommendations in this chart are based on optimum welding characteristics, strength and ductility. For service in corrosive environments, temperatures in excess of 150 F or special finishing requirements consult a Reynolds Welding Engineer.

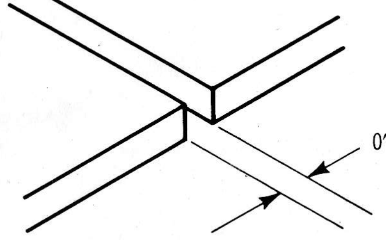
Alloy Combinations (2nd part \ 1st part)	43 319 355 356	214 A-214 F-214 B-214	6061 6062 6063 6101 6151	5083 5456	5454	5086 5154	5052	5005 5050	3004 Alclad 3004	1100 3003 Alclad 3003	1060 EC
1060 EC	4043	4043 5154	4043	5356	4043	5154 4043	4043	1100 4043	4043 5154	1100 4043	1260
1100 3003 Alclad 3003	4043	4043 5154	4043 5154	5356 5154	4043 5154	4043 5154	4043 5154	4043 5154	4043 5154	1100 4043	
3004 Alclad 3004	4043	4043 5154	4043 5154	5356	5356 5554	5356 5154	5154 4043	5154 4043	4043 5154		
5005 5050	4043	4043 5154	4043 5154	5356	5356 5554	5356 5154	5154 4043	5154 4043			
5052	4043	4043 5154	4043 5154	5356	5356 5554	5356 5154	5154 4043				
5086 5154		5356 5154	5356 5154	5356	5356 5554	5356 5154					
5454		5356 5154	5356 5554	5356 5554	5554 5356						
5083 5456		5356 5154	5356	5356							
6061 6062 6063 6101 6151	4043	5356 5154	5154 4043								
214 A-214 B-214 F-214		5356 5154									
43 319 355 356	4043										

Note: 1. 5183 or 5556 may be used in place of 5356.
2. 5254 may be used in place of 5154.

Table 2—GAS METAL ARC (MIG), MANUAL FILLET WELDING



Stock Thickness inch	Position	Welding: Passes Per Joint	Welding: Speed inch/min/Pass	Arc: amps dc	Arc: volts	Argon: Flow Rate cf/hr	Argon: Used per 100 ft cf	Electrode: Diameter inch	Electrode: Speed in./min	Electrode: Used per 100 ft lb
1/8	Flat	1	30	125	20	30	31	3/64	190	2
	H & V	1	24	115	20	30	33	3/64	180	2
	Ovhd	1	24	110	20	40	45	3/64	175	2
3/16	Flat	1	24	190	20	30	55	3/64	255	4-1/2
	H & V	1	20	165	20	35	70	3/64	230	4-1/2
	Ovhd	1	20	180	20	40	75	3/64	245	4-1/2
1/4	Flat	1	24	225	25-29	40	80	1/16	195	7
	H & V	1	20	200	25-29	45	105	1/16	170	7
	Ovhd	1	20	200	25-29	50	115	1/16	170	7
3/8	Flat	3	30	300	25-29	50	175	1/16	275	17
	H & V	3	24	200	25-29	50	280	1/16	170	17
	Ovhd	3	24	220	25-29	60	290	1/16	195	17
1/2	Flat	3	16	340	25-31	60	305	3/32	145	30
	H & V	3	12	225	25-29	60	505	1/16	200	30
	Ovhd	5	18	230	25-29	60	655	1/16	205	30
3/4	Flat	4	16	375	25-31	60	610	3/32	160	66
	H & V	4	8	260	25-29	60	945	1/16	235	66
	Ovhd	10	18	275	25-29	80	1180	1/16	250	66
1	Flat	4	8	425	25-31	60	985	3/32	180	120
	H & V	6	6	260	25-29	80	1715	1/16	235	120
	Ovhd	14	18	290	25-29	80	2025	1/16	265	120



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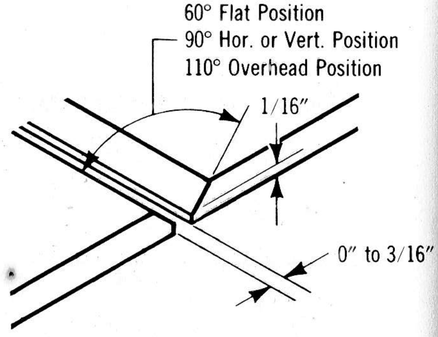

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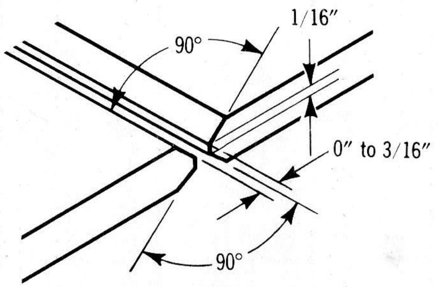

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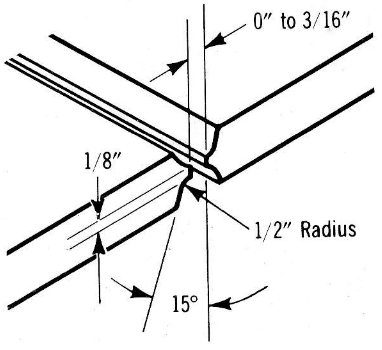

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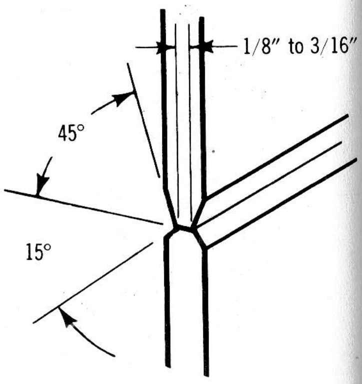

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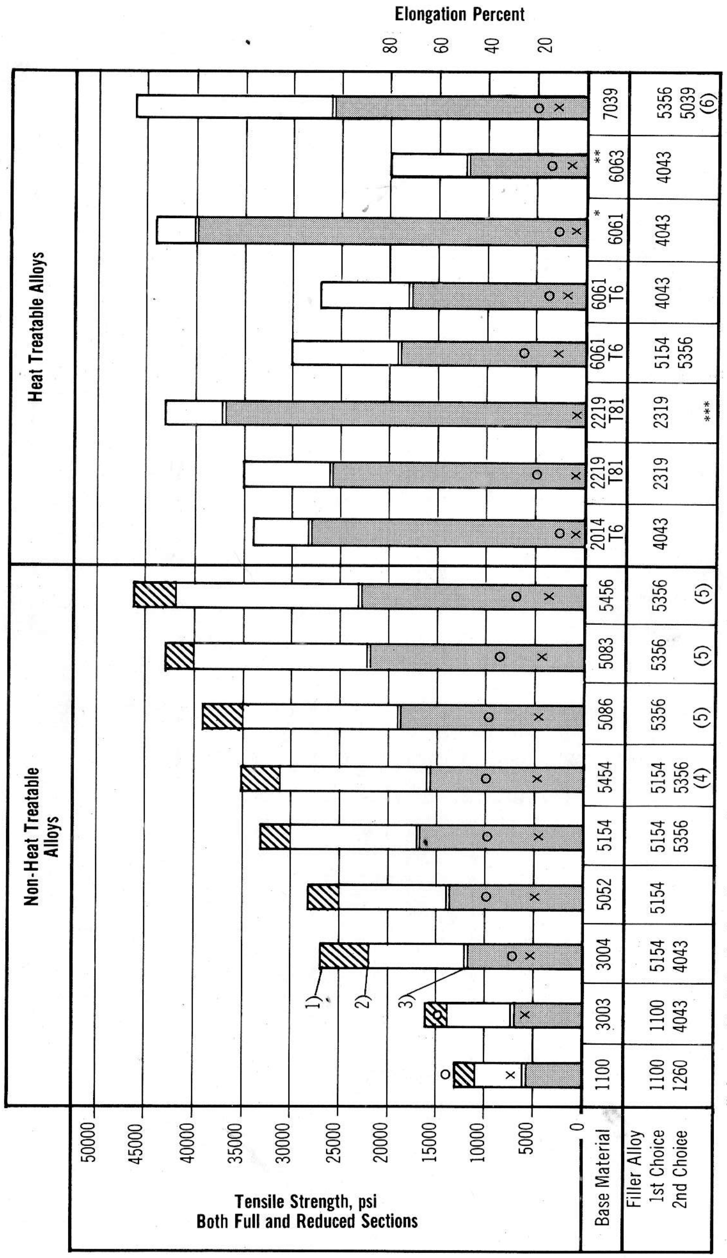
Table 3—GAS METAL ARC (MIG), MANUAL BUTT WELDING

Stock Thickness inch	Joint Preparation	Position	Welding: Passes	Welding: Speed inch/min/Pass	Arc: Current amps dc	Arc: volts	Argon: Flow Rate cf/hr	Argon: Used per 100 feet cf	Electrode: Diameter inch	Electrode: Used per 100 feet lb
1/8	A A A	Flat H & V Ovhd	1	24	110 100 105	20	30 30 40	34 35 58	3/64	2 2 2-1/2
3/16	B B B	Flat H & V Ovhd	1	24 20 18	170 150 160	20	30 35 40	57 75 90	3/64	4-1/2 4-1/2 5
1/4	B B B	Flat H & V Ovhd	1 3 3	24	200 170 180	25 29	40 45 50	105 255 175	1/16	8 8 10
3/8	B C	Flat	2	24	290 275	25 29	50	190 170	1/16	18 15
	B C	H & V	2	24	190 170	25 29	50	315 280	1/16	18 15
	B	Ovhd	5	24	200	25-29	50	380	1/16	23
1/2	B B C	Flat	2 2 3	16	320 290 300	25-31	50	265 295 275	3/32	30 31 29
	C	H & V	2	12	190	25-29	50	505	1/16	29
	B	Ovhd	8	18	225	25-29	80	695	1/16	31
3/4	B C	Flat	4	16	350 330	25-29	60	610 735	3/32	62 72
	B C	H & V	4	8	250 240	25-29	60	925 1125	1/16	62 72
	B	Ovhd	12	18	250	25-29	80	1235	1/16	62
1	B C	Flat	4 6	12 12	400 380	25-31	60	910 760	3/32	105 85
	B C	H & V	4 6	6 6	250 240	25-29	60	1565 1480	1/16	105 95
	B	Ovhd	15	18	275	25-29	80	1880	1/16	105
1½	D	Flat	10	12	425	25-31	80	2185	3/32	200
	E E	Horiz.	24 14	24 24	280 350	25-31	80	1840 1380	1/16 3/32	105
	D D	Vert.	20 12	24 24	260 330	25-31	80	3980 2715	1/16 3/32	200
2	D	Flat	12	12	425	25-31	80	3665	3/32	335
	E E	Horiz.	30 24	24 24	245 425	25-31	80	3845 2140	1/16 3/32	185
	D D	Vert.	26 15	20 20	240 350	25-31	80	6240 3935	1/16 3/32	300
2½	D	Flat	14	12	425	25-31	80	3825	3/32	350
	E E	Horiz.	32 26	24 24	245 350	25-31	80	5615 3540	1/16 3/32	270
3	D	Flat	30	20	450	25-31	80	5180	3/32	500

Table 4—STRENGTH & DUCTILITY OF BUTT WELDS IN ALUMINUM ALLOYS (MIG PROCESS)



1) Average ultimate tensile strength across weld
2) Minimum ultimate tensile strength of annealed plate
3) Average welded yield strength
4) 5554 may also be used
5) 5183, 5556 may also be used
6) 5039 develops higher strength with room temperature 30 day aging

* Heat treated and aged after welding
** Includes -T5, -T6, -T83, -T831, and -T832 tempers
*** Heat treat and age to -T87 after welding
x Elongation in 2" %
o Average free bend elongation

Table 5—**EFFICIENCY OF FILLET WELDS—AS WELDED**

MIG Welding with 4043 Filler Rod 6061-T6 Plate
EFFICIENCY BASED ON 29,000 PSI MAXIMUM

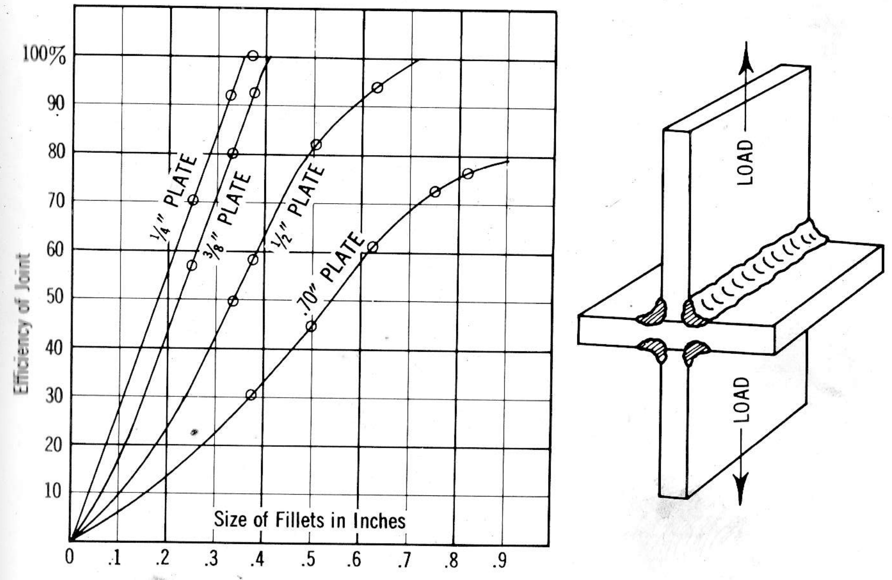
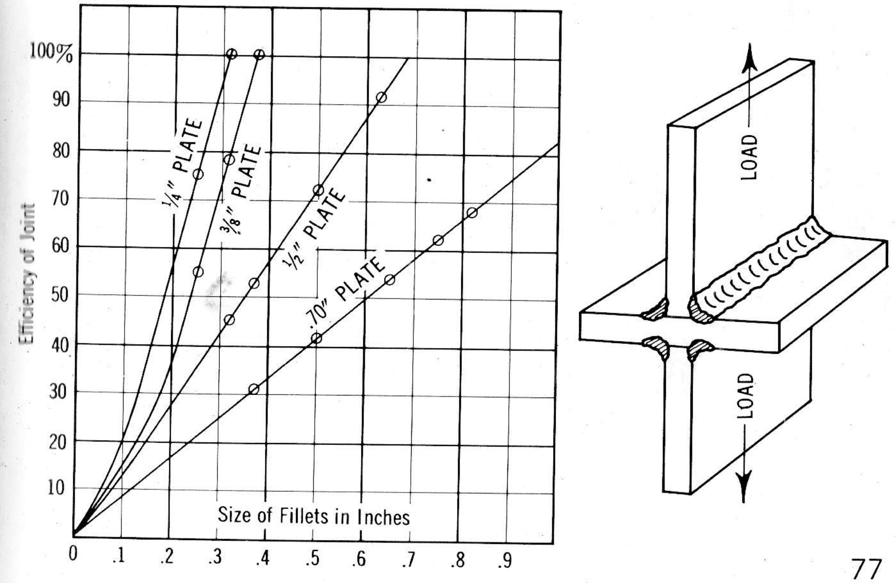


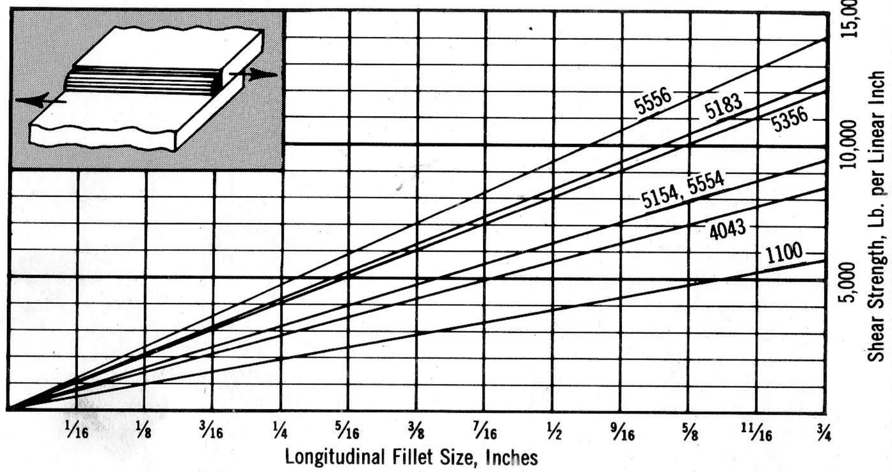
Table 6—**EFFICIENCY OF FILLET WELDS—HEAT TREATED TO FULL -T6**

MIG Welding with 4043 Filler Rod 6061-T6 Plate
EFFICIENCY BASED ON 45,000 PSI



For more detailed information see AWS Welding Handbook, Section 4, Chapter 69.

Table 7—LONGITUDINAL SHEAR STRENGTH OF FILLET WELDS



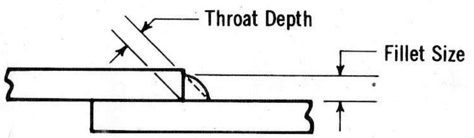


Table 8—TRANSVERSE SHEAR STRENGTH OF FILLET WELDS

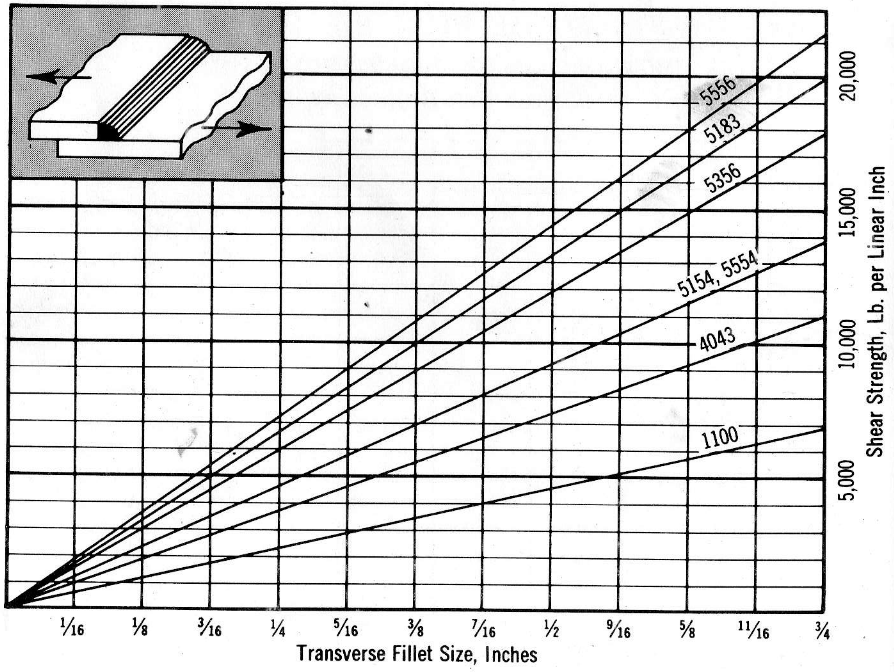


Table 9

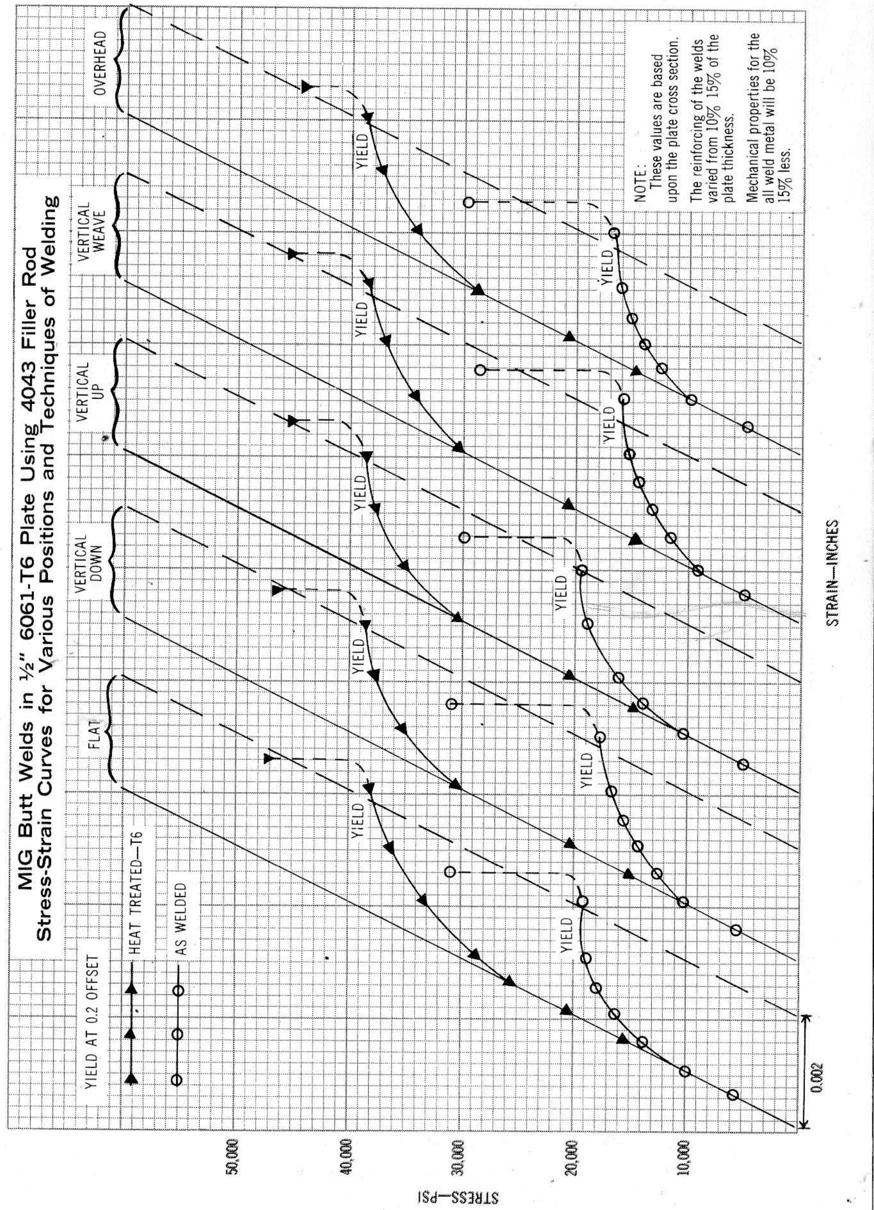


Table 10

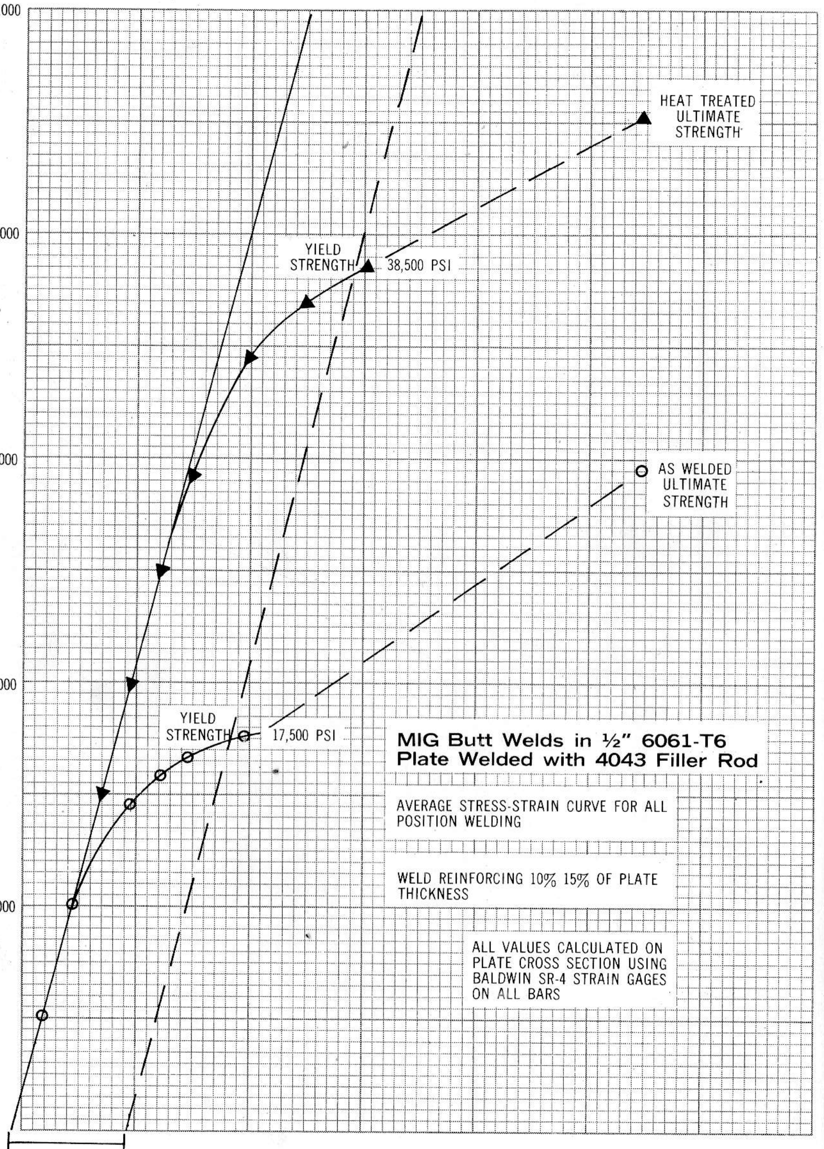


Table 11

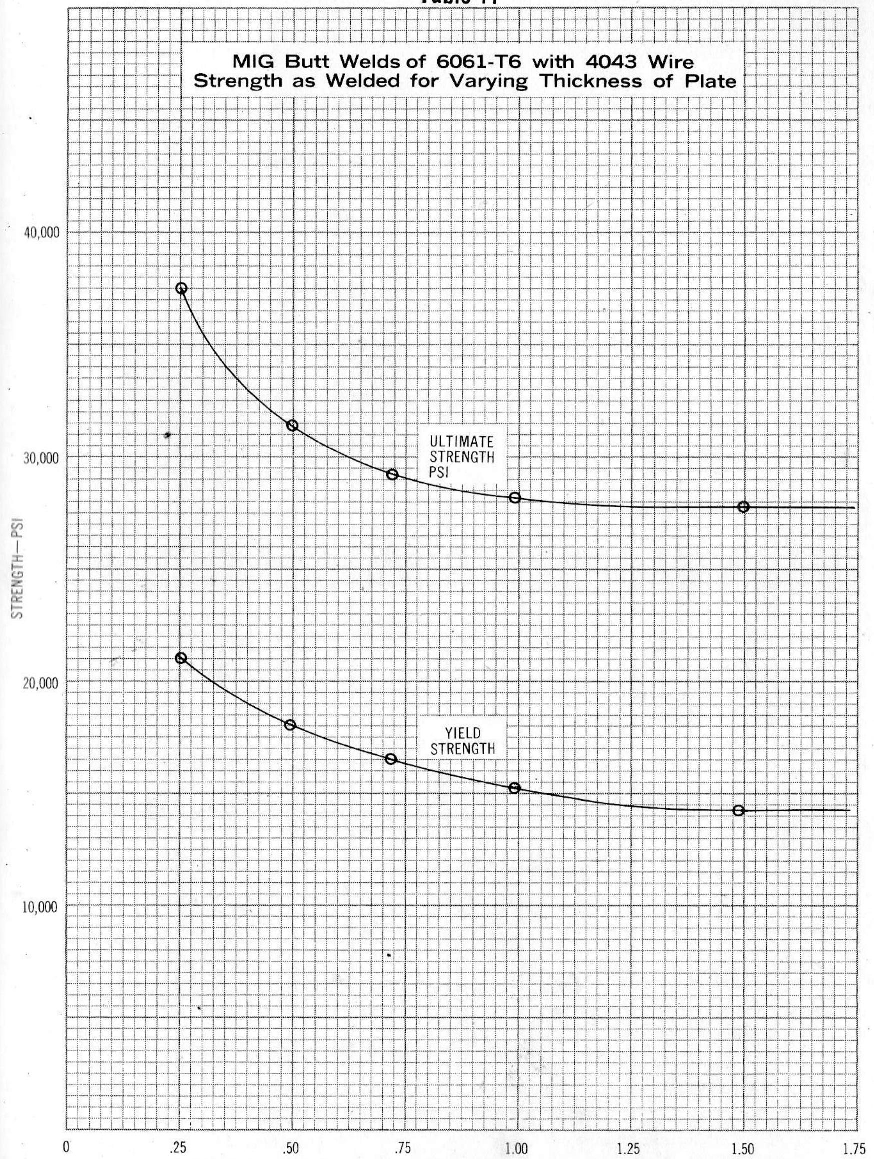
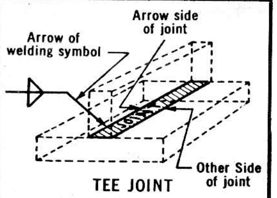
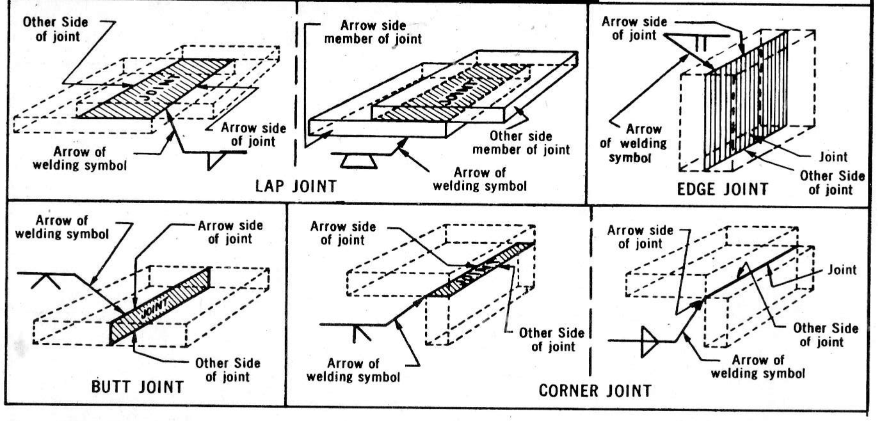


Table 12—STANDARD WELDING SYMBOLS FOR DRAWINGS

(Courtesy American Welding Society)

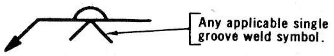
Basic Joints— Identification of Arrow Side and Other Side of Joint and Arrow-Side and Other-Side Member of Joint.





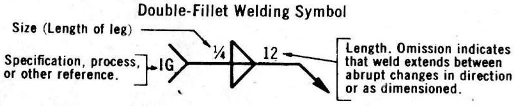
Typical Welding Symbols

Back or Backing Weld Symbol

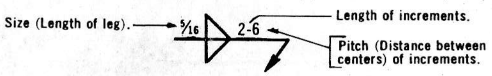


Surfacing Weld Symbol Indicating Built-Up Surface

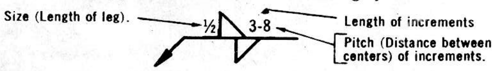
Double-Fillet Welding Symbol



Chain-Intermittent-Fillet Welding Symbol



Staggered Intermittent—Fillet Welding Symbol



Single-V Groove Welding Symbol

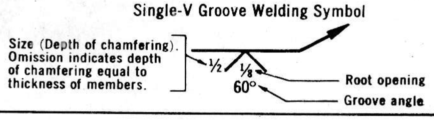
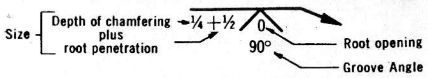


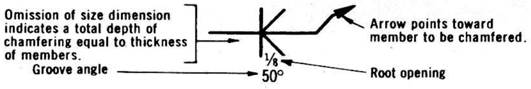
Table 12—(CONTINUED)

Typical Welding Symbols

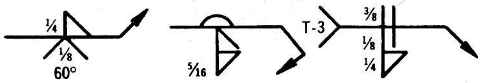
Single-V Groove Welding Symbol Indicating Root Penetration



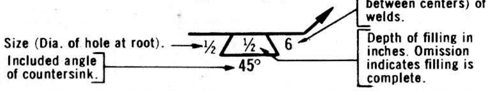
Double-Bevel Groove Welding Symbol



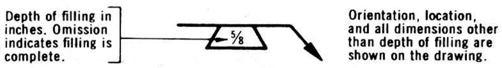
Welding Symbols For Combined Welds



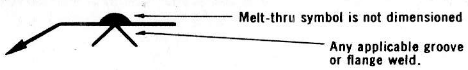
Plug Welding Symbol



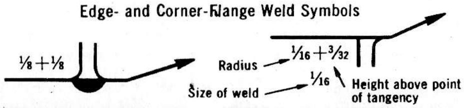
Slot Welding Symbol



Melt-Thru Weld Symbol



Edge- and Corner-Flange Weld Symbols



Location of Elements of A Welding Symbol

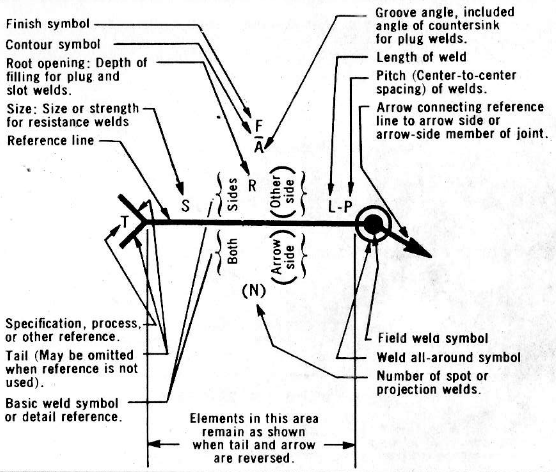


Table 12—(CONCLUDED)

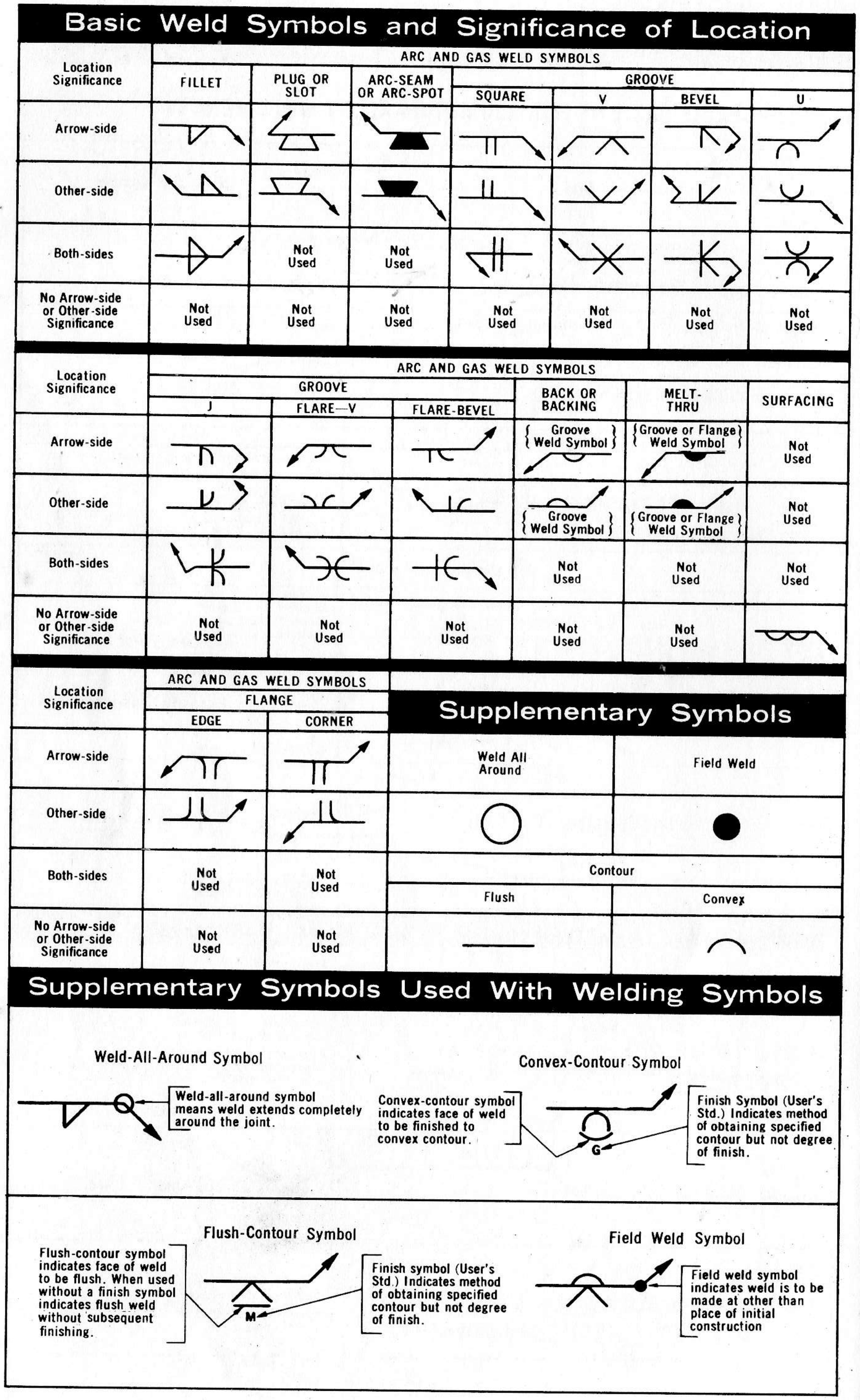


Table 13—SPECIFICATIONS FOR ALUMINUM ALLOY WELDMENTS

Title	Origin and Number
Aluminum and Aluminum Alloy Welding Rod	Federal QQ-R-566, Amend. 2
Electrodes Welding, Bare and Aluminum Alloys	Military E-16053 J
Aluminum Alloy Welding Wire—4043	SAE-AMS 4190 A
Aluminum Alloy Welding Wire—2319	SAE-AMS 4191 A
Tentative Specifications for Aluminum and Aluminum Alloy Welding Rod and Bare Electrode	AWS A5.10-61T ASTM B285-61T
ASME Boiler and Pressure Vessel Code	Sec. IX—Nonferrous Welding Qualification
ASME Boiler and Pressure Vessel Code	Sec. VIII—Porosity Standards
Test—Aircraft Welding Operators—Certification	Military MIL-T-5021 A, Amend. 2
Wel ding of Aluminum Alloys; Process for	MIL-W-8604, Amend. 1
Welding, Inert-Gas, Metal-Arc, Aluminum Alloys, Readily Weldable for Structures, Excluding Armor	MIL-W-45205
Welding, Aluminum Alloy Armor	MIL-W-45206, Amend. 1
X-Ray Standard for Bare Aluminum Alloy Electrode Welds (Same as AWS A5.10-61T; ASTM B285-61T)	MIL-STD-437

QUALITY CONTROL . . . . .

Weld quality will vary with each industrial application. Ship structures, for instance, do not necessarily have to meet the high quality standards of the aircraft and aerospace industries. To meet these requirements, most fabricators work to a specific code or specification.

To determine the quality of aluminum weldments, several methods of inspection are used. These include both destructive and nondestructive tests. Visual examination will quickly determine surface defects such as undercutting, cracks, inclusions, and porosity. This method, however, is merely a superficial means of detecting surface flaws and defects. Quality can only be assured if the part is further subjected to more rigid inspection . . . dye penetrant, black light, ultrasonic, radiographic, or other tests.

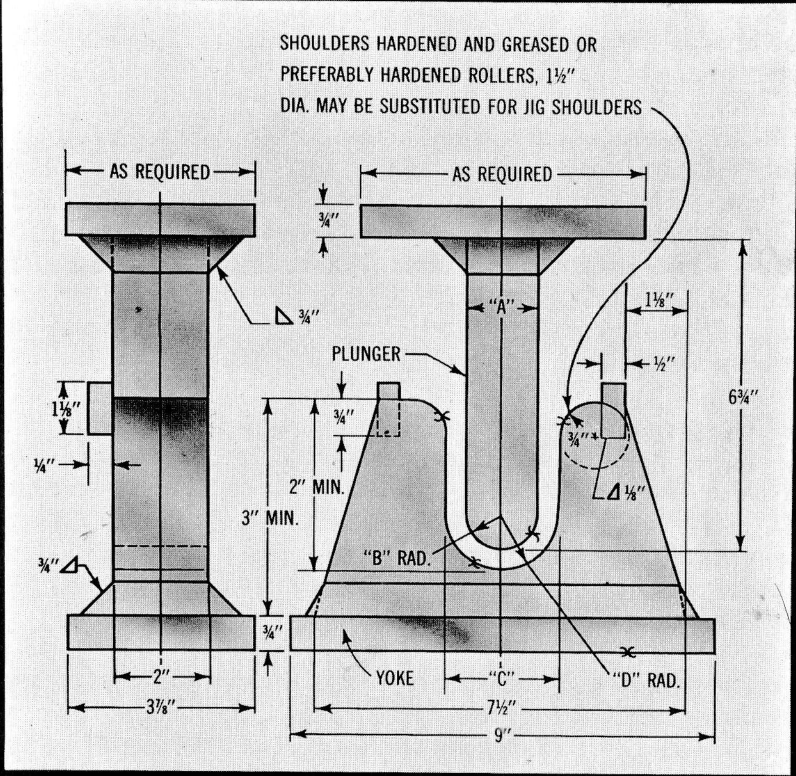
The aerospace industry is perhaps the most quality conscious. There are no gray or questionable areas. The welds either meet the specifications or they do not. After visual examination, dye penetrant is used, followed by radiographic examination. Conscientious x-ray readers can quickly determine most defects that exist in a weldment. To avoid any error, several angle shots are normally taken on all critical areas.

To assure quality and eliminate expensive repairs, the welding operator must be certified and qualified to consistently produce production parts. Quality control begins with the operator. It can only be maintained if he has the proper fixtures and welding equipment.

In maintaining high quality standards, it may be well to point out that repeated repair of minor defects may cause other more serious problems. Not only is unnecessary expense involved, but often additional stresses as well as metallurgical changes such as increased grain growth may result.

These conditions are not normally detected by nondestructive methods, but experience indicates that they may be more detrimental than the original minor defect. Any realistic approach must take into consideration the end use of the welded product. Rewelding to repair minor defects does not always assure highest quality.

GUIDED BEND TEST JIG, SPECIFICATIONS

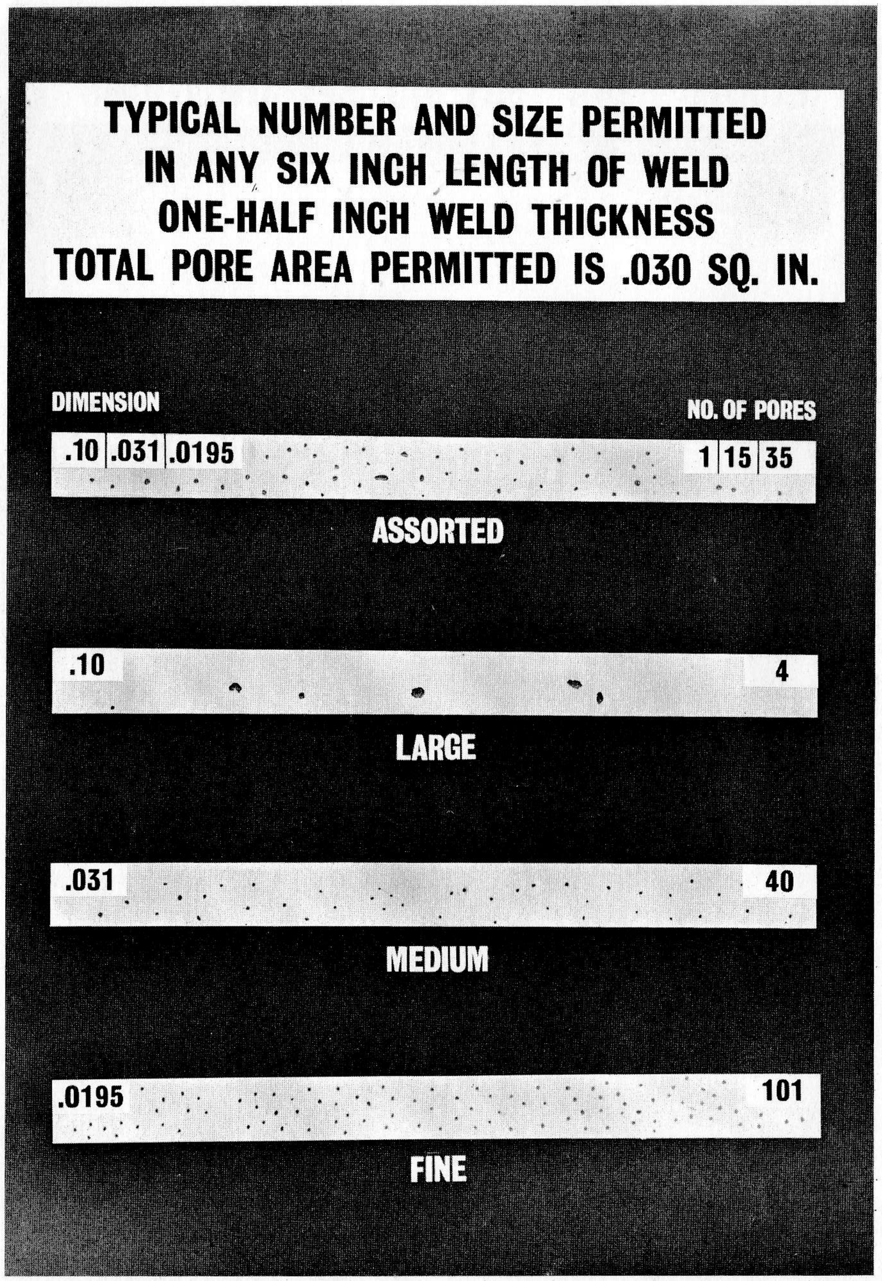


FIGS. Q-8 AND QN-8

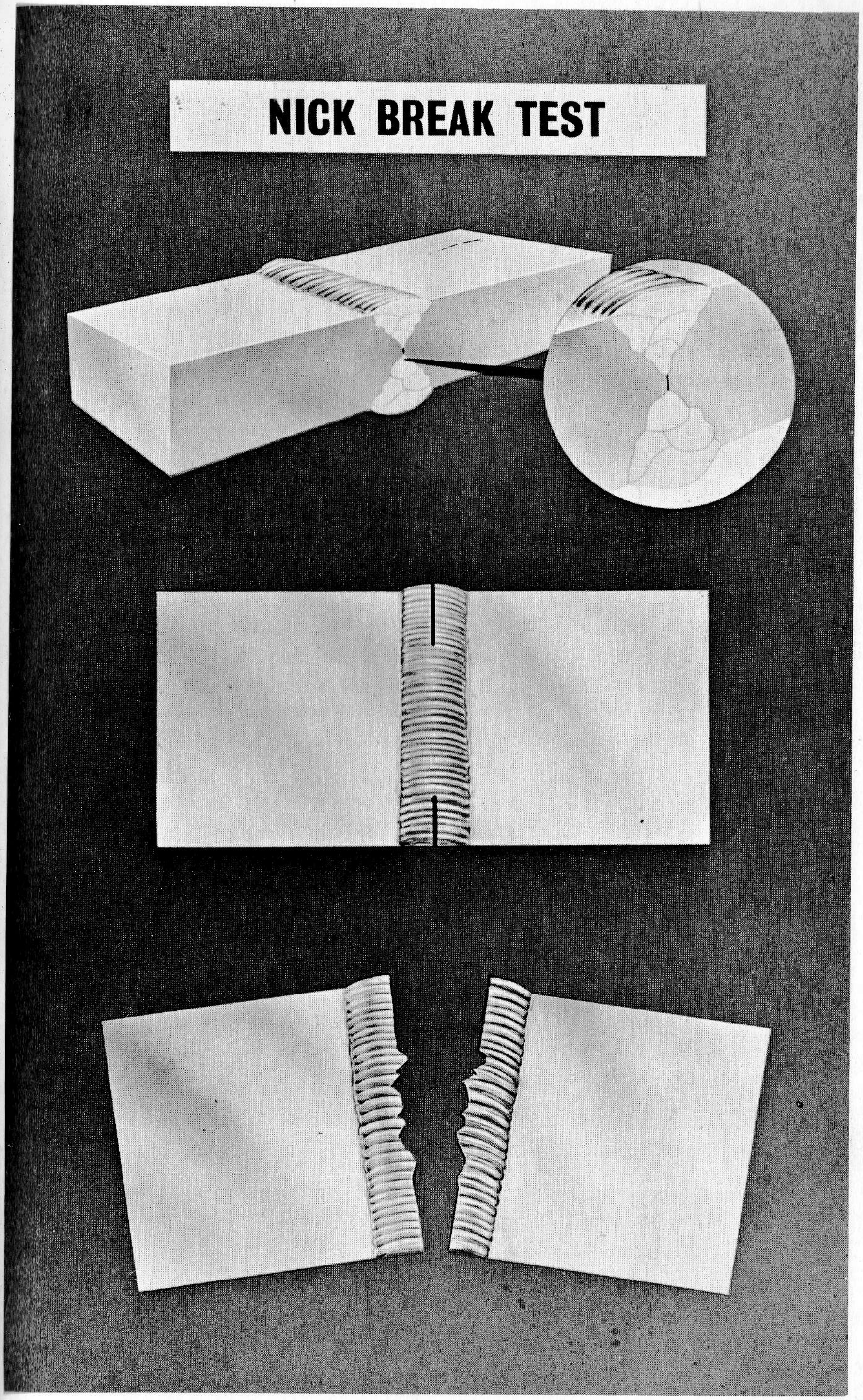
THICKNESS OF SPECIMENS, IN.	A In.	B In.	C In.	D In.	MATERIAL	ALUMINUM ALLOY
⅜ t	1½ 4t	¾ 2t	2⅜ 6t + ⅛	1³⁄₁₆ 3t + ¹⁄₁₆	All Others	1XXX 3XXX 5XXX
⅛	2¹⁄₁₆	1¹⁄₃₂	2⅜	1³⁄₁₆	P-23 and SB-171, Alloy E	6061
⅜ t	2½ 6⅔t	1¼ 3⅓t	3⅜ 8⅔t + ⅛	1¹¹⁄₁₆ 4½t + ¹⁄₁₆	P-11 and P-25	5456

(ASME SECTION IX)

RMC



ASME (SECTION VIII)



INSPECTION . . . . .

The welding inspector is usually responsible for maintaining high quality weld standards. He has many duties and his decisions are of utmost importance on all critical welding work.

He will normally ascertain that all weldors involved on his project are certified and qualified for the particular operation. He will interpret specifications and procedures to be used on construction and approve or disapprove all test results.

He will maintain records and reports of all major details involving weld discrepancies or inferior workmanship.

His most important task, however, is to maintain the production of high quality welds throughout his construction project.

During his inspection of completed welds, he will mark those areas requiring removal or repair. For welds in critical areas, he will usually insist on some form of nondestructive testing. Interpretation of the test results are his responsibility.

The inspector is a man of intelligence as well as integrity. He will not demand aircraft quality welds on parts designed for use on minor low-stress applications.

For high quality aluminum weldments, the inspector will insist that the following rules be observed:

(a) Correct joint design
(b) Proper cleaning prior to assembly
(c) Certified and qualified weldors
(d) Correct welding equipment and filler metal
(e) Correct welding procedure
(f) Optimum quality weld bead appearance
(g) Correct interpretation of nondestructive tests

SAFETY AND HEALTH PRACTICES . . . . .

Welding aluminum does not involve any health or safety hazards which do not already exist in welding other materials. The information presented here is general in nature and should not take the place of specific advice from a competent safety director or engineer.

Eye Protection: Eye protection should be provided by utilizing an approved type weldors' helmet fitted with the deepest shade of lens that permits good visibility without eyestrain or glare. Flash goggles are recommended as additional safety protection from flying sparks, spatter, or accidental flash. The reflectivity of some aluminum surfaces is also considered a potential eye hazard. Eye protection is recommended for all personnel working in the weld area.

Body Protection: Suitable dark clothing should be worn to prevent exposure of the body to harmful ultraviolet rays. White cotton clothing not only reflects the arc, but may eventually disintegrate due to the intense ultraviolet light. Leather clothing is recommended for effective protection against sparks, spatter, and high density arcs.

Ventilation: Adequate ventilation should be provided when there is even a remote possibility of the atmosphere being contaminated or displaced by shielding gases or fumes. Ozone is a potential hazard with any arc welding process, depending upon the metals and gas used.

Certain chlorinated hydrocarbons used for cleaning and degreasing aluminum form another potential hazard. Trichlorethylene, the most commonly used, may result in highly dangerous concentrations of phosgene gas. Cleaning and degreasing should be done in an area widely separated from the welding operations and ample ventilation provided.

Refer to: American Standard "Safety in Electric and Gas Welding and Cutting Operations" ASA Standard Z49.2, and American Welding Society "Recommended Safe Practices for Inert Gas Metal Arc Welding" AWS-A6-1-58.

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